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UTILITY PATENT APPLICATION TRANSMITTAL
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Docket No. 36409-00100

Total Pages in this Submission 96

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Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

SPEECH INFORMATION PROCESSING METHOD AND APPARATUS, AND STORAGE MEDIUM.

and invented by:

Masayuki YAMADA

If a CONTINUATION APPLICATION, *check appropriate box and supply the requisite information:*

☐ **Continuation** ☐ **Divisional** ☐ **Continuation-in-part (CIP)** of prior application No.: _____

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Enclosed are:

Application Elements

1. ☒ Filing fee as calculated and transmitted as described below
2. ☒ Specification having 74 pages and including the following:
   - a. ☒ Descriptive Title of the Invention
   - b. ☐ Cross References to Related Applications *(if applicable)*
   - c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*
   - d. ☐ Reference to Microfiche Appendix *(if applicable)*
   - e. ☒ Background of the Invention
   - f. ☒ Brief Summary of the Invention
   - g. ☒ Brief Description of the Drawings *(if drawings filed)*
   - h. ☒ Detailed Description
   - i. ☒ Claim(s) as Classified Below
   - j. ☒ Abstract of the Disclosure

UTILITY PATENT APPLICATION TRANSMITTAL
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Application Elements (Continued)

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*
   a. ☒ Formal Number of Sheets **15**
   b. ☐ Informal Number of Sheets _____
4. ☐ Oath or Declaration
   a. ☐ Newly executed *(original or copy)* ☐ Unexecuted
   b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*
   c. ☐ With Power of Attorney ☐ Without Power of Attorney
   d. ☐ *DELETION OF INVENTOR(S)*
   Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(usable if Box 4b is checked)*
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Computer Program in Microfiche *(Appendix)*
7. ☐ Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all must be included)*
   a. ☐ Paper Copy
   b. ☐ Computer Readable Copy *(identical to computer copy)*
   c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

Accompanying Application Parts

8. ☐ Assignment Papers *(cover sheet & document(s))*
9. ☐ 37 CFR 3.73(B) Statement *(when there is an assignee)*
10. ☐ English Translation Document *(if applicable)*
11. ☐ Information Disclosure Statement/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☐ Acknowledgment postcard
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Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. ☐ Additional Enclosures *(please identify below):*

Fee Calculation and Transmittal

CLAIMS AS FILED

For	#Filed	#Allowed	#Extra		Rate	Fee
Total Claims	48	- 20 =	28	x	$18.00	$504.00
Indep. Claims	8	- 3 =	5	x	$78.00	$390.00
Multiple Dependent Claims (check if applicable) ☐						$0.00
					BASIC FEE	$690.00
OTHER FEE *(specify purpose)*						$0.00
					TOTAL FILING FEE	$1,584.00

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Signature

Dated: **August 1, 2000**

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Applicant: Masayuki YAMADA
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For: SPEECH INFORMATION PROCESSING METHOD AND APPARATUS, AND STORAGE MEDIUM
I hereby certify that this :

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TITLE OF THE INVENTION

SPEECH INFORMATION PROCESSING METHOD AND APPARATUS, AND STORAGE MEDIUM

FIELD OF THE INVENTION

The present invention relates to a technique for synthesizing speech by using a speech segment dictionary.

BACKGROUND OF THE INVENTION

A speech synthesizing technique for synthesizing speech by using a computer uses a speech segment dictionary. This speech segment dictionary stores speech segments in units (synthetic units) of speech segments, CV/VC, or VCV. To synthesize speech, appropriate speech segments are selected from this speech segment dictionary and modified and connected to generate desired synthetic speech. A flow chart in Fig. 15 explains this process.

In step S131, speech contents expressed by kana-kanji mixed text and the like are input. In step S132, the input speech contents are analyzed to obtain a speech segment symbol string {p0, p1,...} and parameters for determining prosody. The flow then advances to step S133 to determine the prosody such as the speech segment time length, fundamental frequency, and power. In speech segment dictionary look-up step S134, speech segments {w0, w1,...}

appropriate for the speech segment symbol string {p0, p1,...} obtained by the input analysis in step S132 and the prosody obtained by the prosody determination in step S133 are retrieved from the speech segment dictionary. The flow advances to step S135, and the speech segments {w0, w1,...} obtained by the speech segment dictionary retrieval in step S134 are modified and concatenated to match the prosody determined in step S133. In step S136, the result of the speech segment modification and concatenation in step S135 is output as a synthetic speech.

Waveform editing is one effective method of speech synthesis. This method, e.g., superposes waveforms and changes pitches in synchronism with vocal cord vibrations. The method is advantageous in that synthetic speech close to a natural utterance can be generated with a small amount of arithmetic operations. When a method like this is used, a speech segment dictionary is composed of indexes for retrieval, waveform data (also called speech segment data) corresponding to individual speech segments, and auxiliary information of the data. In this case, all speech segment data registered in the speech segment dictionary are often encoded using the μ-law or ADPCM (Adaptive Differential Pulse Code Modulation).

The above prior art has the following problems.

First, when all speech segment data registered in the speech segment dictionary are encoded by using an encoding

scheme such as the μ-law or A-law, no sufficient compression efficiency can be obtained since each speech segment data is nonuniformly quantized using a fixed quantization table. This is so because a quantization table must be so designed that a minimum quality can be maintained for all types of speech segments.

Second, when all speech segment data registered in the speech segment dictionary are encoded using an encoding scheme such as ADPCM, the operation amount in decoding increases by the operation amount of an adaptive algorithm. This is so because the advantage (small processing amount) of the waveform editing method is impaired if a large operation amount is required for decoding.

SUMMARY OF THE INVENTION

The present invention has been made in consideration of the above prior art, and has as its object to provide a technique which very efficiently reduces a storage capacity necessary for a speech segment dictionary without degrading the quality of speech segments registered in the speech segment dictionary.

Also, the present invention has been made in consideration of the above prior art, and has as its another object to provide a technique which generates natural, high-quality synthetic speech.

To achieve the above objects, a speech information processing method of the present invention is a speech information processing method of generating a speech segment dictionary for holding a plurality of speech segments, characterized by comprising the selection step of selecting an encoding method of encoding a speech segment from a plurality of encoding methods, the encoding step of encoding the speech segment by using the selected encoding method, and the storage step of storing the encoded speech segment in a speech segment dictionary.

A storage medium of the present invention is characterized by storing a control program for allowing a computer to realize the above speech information processing method.

A speech information processing apparatus of the present invention is a speech information processing apparatus for generating a speech segment dictionary for holding a plurality of speech segments, characterized by comprising selecting means for selecting an encoding method of encoding a speech segment from a plurality of encoding methods, encoding means for encoding the speech segment by using the selected encoding method, and storage means for storing the encoded speech segment in a speech segment dictionary.

A speech information processing method of the present invention is a speech information processing method of

synthesizing speech by using a speech segment dictionary for holding a plurality of speech segments, characterized by comprising the selection step of selecting, from a plurality of decoding methods, a decoding method of decoding a speech segment read out from the speech segment dictionary, the decoding step of decoding the speech segment by using the selected decoding method, and the speech synthesizing step of synthesizing speech on the basis of the decoded speech segment.

A storage medium of the present invention is characterized by storing a control program for allowing a computer to realize the above speech information processing method.

A speech information processing apparatus of the present invention is a speech information processing apparatus for synthesizing speech by using a speech segment dictionary for holding a plurality of speech segments, characterized by comprising selecting means for selecting, from a plurality of decoding methods, a decoding method of decoding a speech segment read out from the speech segment dictionary, decoding means for decoding the speech segment by using the selected decoding method, and speech synthesizing means for synthesizing speech on the basis of the decoded speech segment.

A speech information processing method of the present invention is a speech information processing method of

generating a speech segment dictionary for holding a plurality of speech segments, characterized by comprising the setting step of setting an encoding method of encoding a speech segment in accordance with the type of the speech segment, the encoding step of encoding the speech segment by using the set encoding method, and the storage step of storing the encoded speech segment in a speech segment dictionary.

A storage medium of the present invention is characterized by comprising a control program for allowing a computer to realize the above speech information processing method.

A speech information processing apparatus of the present invention is a speech information processing apparatus for generating a speech segment dictionary for holding a plurality of speech segments, characterized by comprising setting means for setting an encoding method of encoding a speech segment in accordance with the type of the speech segment, encoding means for encoding the speech segment by using the set encoding method, and storage means for storing the encoded speech segment in a speech segment dictionary.

A speech information processing method of the present invention is a speech information processing method of synthesizing speech by using a speech segment dictionary for holding a plurality of speech segments, characterized by

comprising the setting step of setting a decoding method of decoding a speech segment read out from the speech segment dictionary in accordance with the type of the speech segment, the decoding step of decoding the speech segment by using the set decoding method, and the speech synthesizing step of synthesizing speech on the basis of the decoded speech segment.

A storage medium of the present invention is characterized by comprising a control program for allowing a computer to realize the above speech information processing method.

A speech information processing apparatus of the present invention is a speech information processing apparatus for synthesizing speech by using a speech segment dictionary for holding a plurality of speech segments, characterized by comprising setting means for setting a decoding method of decoding a speech segment read out from the speech segment dictionary in accordance with the type of the speech segment, decoding means for decoding the speech segment by using the set decoding method, and speech synthesizing means for synthesizing speech on the basis of the decoded speech segment.

Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like

reference characters designate the same or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Fig. 1 is block diagram showing the hardware configuration of a speech synthesizing apparatus according to each embodiment of the present invention;

Fig. 2 is a flow chart for explaining a speech segment dictionary formation algorithm in the first embodiment of the present invention;

Fig. 3 is a flow chart for explaining a speech synthesis algorithm in the first embodiment of the present invention;

Fig. 4 is a flow chart for explaining a speech segment dictionary formation algorithm in the second embodiment of the present invention;

Fig. 5 is a flow chart for explaining a speech synthesis algorithm in the second embodiment of the present invention;

Fig. 6 is a flow chart for explaining a speech segment dictionary formation algorithm in the third embodiment of the present invention;

Fig. 7 is a flow chart for explaining the speech segment dictionary formation algorithm in the third embodiment of the present invention;

Fig. 8 is a flow chart for explaining a speech synthesis algorithm in the third embodiment of the present invention;

Fig. 9 is a flow chart for explaining a speech segment dictionary formation algorithm in the fourth embodiment of the present invention;

Fig. 10 is a flow chart for explaining a speech synthesis algorithm in the fourth embodiment of the present invention;

Fig. 11 is a flow chart for explaining a speech segment dictionary formation algorithm in the fifth embodiment of the present invention;

Fig. 12 is a flow chart for explaining a speech synthesis algorithm in the fifth embodiment of the present invention;

Fig. 13 is a flow chart for explaining a speech segment dictionary formation algorithm in the sixth embodiment of the present invention;

Fig. 14 is a flow chart for explaining a speech synthesis algorithm in the sixth embodiment of the present invention; and

Fig. 15 is a flow chart showing a general speech synthesizing process.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described in detail below with reference to the accompanying drawings. In these embodiments, (1) a method of forming a speech segment dictionary (a speech segment dictionary formation algorithm) and (2) a method of synthesizing speech by using this speech segment dictionary (a speech synthesis algorithm) will be described in detail.

Fig. 1 is a block diagram showing an outline of the functional configuration of a speech information processing apparatus according to the embodiments of the present invention. A speech segment dictionary formation algorithm and a speech synthesis algorithm in each embodiment are realized by using this speech information processing apparatus.

Referring to Fig. 1, a central processing unit (CPU) 100 executes numerical operations and various control processes and controls operations of individual units (to be described later) connected via a bus 105. A storage device 101 includes, e.g., a RAM and ROM and stores various control programs executed by the CPU 100, data, and the like. The storage device 101 also temporarily stores various data necessary for the control by the CPU 100. An external storage device 102 is a hard disk device or the like and includes speech segment database 111 and a speech segment dictionary 112. This speech segment database 111 holds speech segments

before registration in the speech segment dictionary 112 (i.e., non-compressed speech segments). An output device 103 includes a monitor for displaying the operation statuses of diverse programs, a loudspeaker for outputting synthesized speech, and the like. An input device 104 includes, e.g., a keyboard and a mouse. By using this input device 104, a user can control a program for forming the speech segment dictionary 112, control a program for synthesizing speech by using the speech segment dictionary 112, and input text (containing a plurality of character strings) as an object of speech synthesis.

On the basis of the above configuration, a speech segment dictionary formation algorithm and a speech synthesis algorithm in each embodiment will be described below.

[First Embodiment]

A speech segment dictionary formation algorithm and a speech synthesis algorithm according to the first embodiment of the present invention will be described below by using the speech processing apparatus shown in Fig. 1.

In the first embodiment, one of a plurality of encoding methods (more specifically, a 7-bit μ-law scheme and an 8-bit μ-law scheme) different in the number of quantization steps is selected for each speech segment to be registered in a speech segment dictionary 112. Note that a speech segment to be registered in the speech segment dictionary 112 is

composed of a phoneme, semi-phoneme, diphone (e.g., CV or VC), VCV (or CVC), or combinations thereof.

(Formation of speech segment dictionary)

Fig. 2 is a flow chart for explaining the speech segment dictionary formation algorithm in the first embodiment of the present invention. A program for achieving this algorithm is stored in a storage device 101. A CPU 100 reads out this program from the storage device 101 on the basis of an instruction from a user and executes the following procedure.

In step S201, the CPU 100 initializes an index $\underline{i}$, which indicates each of N speech segment data (each speech segment data is non-compressed) stored in speech segment database 111 of an external storage device 102, to "0". Note that this index $\underline{i}$ is stored in the storage device 101.

In step S202, the CPU 100 reads out ith speech segment data Wi indicated by this index $\underline{i}$. Assume that the readout data Wi is

$$Wi = \{x0, x1, \ldots, xT-1\}$$

where T is the time length (in units of samples) of Wi.

In step S203, the CPU 100 encodes the speech segment data Wi read out in step S202 by using the 7-bit μ-law scheme. Assume that the result of the encoding is

$$Ci = \{c0, c1, \ldots, cT-1\}$$

In step S204, the CPU 100 calculates encoding distortion ρ produced by the 7-bit μ-law encoding in step

S203. In this embodiment, a mean square error ρ is used as a measure of this encoding distortion. This mean square error ρ can be represented by

$$\rho = (1/T) \cdot \Sigma (xt - \mu(7)^{-1}(ct))^2 \quad \ldots(1)$$

where $\mu(7)^{-1}()$ is a 7-bit μ-law decoding function. In this equation, "Σ" is the summation from t = 0 to t = T - 1.

In step S205, the CPU 100 checks whether the encoding distortion ρ calculated in step S204 is larger than a predetermined threshold value $\rho 0$. If $\rho > \rho 0$, the CPU 100 determines that the waveform of the speech segment data Wi is distorted by encoding using the 7-bit μ-law scheme. Therefore, in step S206 the CPU 100 switches the encoding method to the 8-bit μ-law scheme having a different number of quantization bits. In other cases, the flow advances to step S207. In step S206, the CPU 100 encodes the speech segment data Wi read out in step S202 by using the 8-bit μ-law scheme. Assume that the result of the encoding is

Ci = {c0, c1,..., cT-1}

In step S207, the CPU 100 writes encoding information of the phoneme data Wi and the like in the phoneme dictionary 112. In addition to the encoding information, the CPU 100 writes information necessary to decode the phoneme data Wi. This encoding information specifies the encoding method by which the speech segment data Wi is encoded:

The encoding information is "0" if the encoding method is the 7-bit μ-law scheme

The encoding information is "1" if the encoding method is the 8-bit μ-low scheme

In step S208, the CPU 100 writes the speech segment data Wi encoded by one encoding scheme in the speech segment dictionary 112. In step S209, the CPU 100 checks whether the above processing is performed for all of the N speech segment data. If i = N - 1, the CPU 100 completes this algorithm. If not, in step S210 the CPU 100 adds 1 to the index i, the flow returns to step S202, and the CPU 100 reads out speech segment data designated by the updated index i. The CPU 100 repeatedly executes this processing for all of the N speech segment data.

In the speech segment dictionary formation algorithm of the first embodiment as described above, an encoding scheme can be selected from the 7-bit μ-law scheme and the 8-bit μ-law scheme for each speech segment to be registered in the speech segment dictionary 112. With this arrangement, a storage capacity necessary for the speech segment dictionary can be very efficiently reduced without deteriorating the quality of speech segments to be registered in the speech segment dictionary. Also, a larger number of types of speech segments than in conventional speech segment dictionaries can be registered in a speech segment dictionary having a storage capacity equivalent to those of the conventional dictionaries.

In the first embodiment, the aforementioned speech segment dictionary formation algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech segment dictionary formation algorithm can also be constituted by hardware.

(Speech synthesis)

Fig. 3 is a flow chart for explaining the speech synthesis algorithm in the first embodiment of the present invention. A program for achieving this algorithm is stored in the storage device 101. The CPU 100 reads out this program on the basis of an instruction from a user and executes the following procedure.

In step S301, the user inputs a character string in Japanese, English, or some other language by using the keyboard and the mouse of an input device 104. In the case of Japanese, the user inputs a character string expressed by kana-kanji mixed text. In step S302, the CPU 100 analyzes the input character string and obtains the speech segment sequence of this character string and parameters for determining the prosody of this character string. In step S303, on the basis of the prosodic parameters obtained in step S302, the CPU 100 determines prosody such as a duration length (the prosody for controlling the length of a voice), fundamental frequency (the prosody for controlling the pitch of a voice), and power (the prosody for controlling the strength of a voice).

In step S304, the CPU 100 obtains an optimum speech segment sequence on the basis of the speech segment sequence obtained in step S302 and the prosody determined in step S303. The CPU 100 selects one speech segment contained in this speech segment sequence and retrieves speech segment data corresponding to the selected speech segment and encoding information corresponding to this speech segment data. If the speech segment dictionary 112 is stored in a storage medium such as a hard disk, the CPU 100 sequentially seeks to storage areas of encoding information and speech segment data. If the speech segment dictionary 112 is stored in a storage medium such as a RAM, the CPU 100 sequentially moves a pointer (address register) to storage areas of encoding information and speech segment data.

In step S305, the CPU 100 reads out the encoding information retrieved in step S304 from the speech segment dictionary 112. This encoding information indicates the encoding method of the speech segment data retrieved in step S304:

If the encoding information is "0", the encoding method is the 7-bit μ-law scheme

If the encoding information is "1", the encoding method is the 8-bit μ-law scheme

In step S306, the CPU 100 examines the encoding information read out in step S305. If the encoding information is "0", the CPU 100 selects a decoding method

corresponding to the 7-bit μ-law scheme, and the flow advances to step S307. If the encoding information is "1", the CPU 100 selects a decoding method corresponding to the 8-bit μ-law scheme, and the flow advances to step S309.

In step S307, the CPU 100 reads out the speech segment data (encoded by the 7-bit μ-law scheme) retrieved in step S304 from the speech segment dictionary 112. In step S308, the CPU 100 decodes the speech segment data encoded by the 7-bit μ-law scheme.

On the other hand, in step S309 the CPU 100 reads out the speech segment data (encoded by the 8-bit μ-law scheme) retrieved in step S304 from the speech segment dictionary 112. In step S310, the CPU 100 decodes the speech segment data encoded by the 8-bit μ-law scheme.

In step S311, the CPU 100 checks whether speech segment data corresponding to all speech segments contained in the speech segment sequence obtained in step S304 are decoded. If all speech segment data are decoded, the flow advances to step S312. If speech segment data not decoded yet is present, the flow returns to step S304 to decode the next speech segment data.

In step S312, on the basis of the prosody determined in step S303, the CPU 100 modifies and concatenates the decoded speech segments (i.e., edits the waveform). In step S313, the CPU 100 outputs the synthetic speech obtained in step S312 from the loudspeaker of an output device 103.

In the speech synthesis algorithm of the first embodiment as described above, a desired speech segment can be decoded by a decoding method corresponding to the 7-bit μ-law scheme or the 8-bit μ-law scheme. With this arrangement, natural, high-quality synthetic speech can be generated.

In the first embodiment, the aforementioned speech synthesis algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech synthesis algorithm can also be constituted by hardware.

[First Modification of the First Embodiment]

In the first embodiment, speech segment data whose encoding distortion is larger than a predetermined threshold value is encoded by the 8-bit μ-law scheme. However, it is also possible to obtain the encoding distortion after encoding is performed by the 8-bit μ-law scheme, and register speech segment data whose encoding distortion is larger than a predetermined threshold value in a speech segment dictionary without encoding the data. With this arrangement, degradation of the quality of an unstable speech segment (e.g., a speech segment classified into a voiced fricative sound or a plosive) can be prevented. Also, natural, high-quality synthetic speech can be generated by using a speech segment dictionary thus formed.

[Second Modification of the First Embodiment]

In the first embodiment, an encoding method is selected from the 7-bit μ-law scheme and the 8-bit μ-law scheme in accordance with the encoding distortion. However, it is also possible, in accordance with the type (e.g., a voiced fricative sound, plosive, nasal sound, some other voiced sound, or unvoiced sound) of speech segment, to choose to encode the speech segment by the 7-bit μ-law scheme or the 8-bit μ-law scheme or to register the speech segment in the speech segment dictionary 112 without encoding it. For example, a speech segment of the type of a voiced fricative sound and plosive may be registered in the speech segment dictionary 112 without encoding it, and a speech segment of the type of nasal sound and unvoiced sound may be registered in the speech segment dictionary 112 by encoding with the 7-bit μ-law scheme, and a speech segment of the type of other voiced sound may be registered in the speech segment dictionary 112 by encoding with the 8-bit μ-law scheme.

[Second Embodiment]

A speech segment dictionary formation algorithm and a speech synthesis algorithm according to the second embodiment of the present invention will be described below by using the speech processing apparatus shown in Fig. 1.

In the second embodiment, one of a plurality of encoding methods using different quantization code books is selected for each speech segment to be registered in a speech segment dictionary 112. Note that a speech segment to be

registered in the speech segment dictionary 112 is composed of a phoneme, semi-phoneme, diphone (e.g., CV or VC), VCV (or CVC), or combinations thereof.

(Formation of speech segment dictionary)

Fig. 4 is a flow chart for explaining the speech segment dictionary formation algorithm in the second embodiment of the present invention. A program for achieving this algorithm is stored in a storage device 101. A CPU 100 reads out this program from the storage device 101 on the basis of an instruction from a user and executes the following procedure.

In step S401, the CPU 100 initializes an index i, which indicates each of N speech segment data (each speech segment data is non-compressed) stored in speech segment database 111 of an external storage device 102, to "0". Note that this index i is stored in the storage device 101.

In step S402, the CPU 100 reads out ith speech segment data Wi indicated by this index i. Assume that the readout data Wi is

$$Wi = \{x0, x1, \ldots, xT-1\}$$

where T is the time length (in units of samples) of Wi.

In step S403, the CPU 100 forms a scalar quantization code book Qi of the speech segment data Wi read out in step S402. More specifically, the CPU 100 decodes the encoded speech segment data Wi by using the scalar quantization code book Qi and so designs that a mean square error ρ of decoded

data sequence Yi = {y0, y1,..., yT-1} is a minimum (i.e., the encoding distortion is a minimum). In this case, an algorithm such as an LBG method is usable. With this arrangement, the distortion of the waveform of a speech segment produced by encoding can be minimized. Note that the mean square error ρ can be represented by

$$\rho = (1/T) \cdot \Sigma (xt - yt)^2 \quad \ldots(2)$$

where "Σ" is the summation from t = 0 to t = T - 1.

In step S404, the CPU 100 writes the scalar quantization code book Qi formed in step S403 and the like in the speech segment dictionary 112. In addition to the quantization code book Qi, the CPU 100 writes information necessary to decode the speech segment data Wi. In step S405, the CPU 100 encodes (scalar-quantizes) the speech segment data Wi by using the quantization code book Qi formed in step S403.

Assuming the code book Qi is

Qi = {q0, q1,..., qN-1} (N is the quantization step), a code ct corresponding to xt ($\in$Wi) can be represented by

$$ct = \text{argn min } (xt - qn)^2 \quad (0 \leqq n < N) \quad \ldots(3)$$

In step S406, the CPU 100 writes speech segment data Ci (= {c0, c1,..., cT-1} encoded in step S405 into the speech segment dictionary 112. In step S407, the CPU 100 checks whether the above processing is performed for all of the N speech segment data. If i = N - 1, the CPU 100 completes this algorithm. If not, in step S408 the CPU 100 adds 1 to the

index $\underline{i}$, the flow returns to step S402, and the CPU 100 reads out speech segment data designated by the updated index $\underline{i}$. The CPU 100 repeatedly executes this processing for all of the N speech segment data.

In the speech segment dictionary formation algorithm of the second embodiment as described above, it is possible to form a quantization code book for each speech segment to be registered in the speech segment dictionary 112 and scalar-quantize the speech segment by using the formed quantization code book. With this arrangement, a storage capacity necessary for the speech segment dictionary can be very efficiently reduced without deteriorating the quality of speech segments to be registered in the speech segment dictionary. Also, a larger number of types of speech segments than in conventional speech segment dictionaries can be registered in a speech segment dictionary having a storage capacity equivalent to those of the conventional dictionaries.

In the second embodiment, the aforementioned speech segment dictionary formation algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech segment dictionary formation algorithm can also be constituted by hardware.

(Speech synthesis)

Fig. 5 is a flow chart for explaining the speech synthesis algorithm in the second embodiment of the present

invention. A program for achieving this algorithm is stored in the storage device 101. The CPU 100 reads out this program on the basis of an instruction from a user and executes the following procedure.

In step S501, the user inputs a character string in Japanese, English, or some other language by using the keyboard and the mouse of an input device 104. In the case of Japanese, the user inputs a character string expressed by kana-kanji mixed text. In step S502, the CPU 100 analyzes the input character string and obtains the speech segment sequence of this character string and parameters for determining the prosody of this character string. In step S503, on the basis of the prosodic parameters obtained in step S502, the CPU 100 determines prosody such as a duration length (the prosody for controlling the length of a voice), fundamental frequency (the prosody for controlling the pitch of a voice), and power (the prosody for controlling the strength of a voice).

In step S504, the CPU 100 obtains an optimum speech segment sequence on the basis of the speech segment sequence obtained in step S502 and the prosody determined in step S503. The CPU 100 selects one speech segment contained in this speech segment sequence and retrieves a scalar quantization code book and speech segment data corresponding to the selected speech segment. If the speech segment dictionary 112 is stored in a storage medium such as a hard disk, the

CPU 100 sequentially seeks to storage areas of scalar quantization code books and speech segment data. If the speech segment dictionary 112 is stored in a storage medium such as a RAM, the CPU 100 sequentially moves a pointer (address register) to storage areas of scalar quantization code books and speech segment data.

In step S505, the CPU 100 reads out the scalar quantization code book retrieved in step S504 from the speech segment dictionary 112. In step S506, the CPU 100 reads out the speech segment data retrieved in step S504 from the speech segment dictionary 112. In step S507, the CPU 100 decodes the speech segment data read out in step S506 by using the scalar quantization code book read out in step S505.

In step S508, the CPU 100 checks whether speech segment data corresponding to all speech segments contained in the speech segment sequence obtained in step S504 are decoded. If all speech segment data are decoded, the flow advances to step S509. If speech segment data not decoded yet is present, the flow returns to step S504 to decode the next speech segment data.

In step S509, on the basis of the prosody determined in step S503, the CPU 100 modifies and connects the decoded speech segments (i.e., edits the waveform). In step S510, the CPU 100 outputs the synthetic speech obtained in step S509 from the loudspeaker of an output device 103.

In the speech synthesis algorithm of the second embodiment as described above, a desired speech segment can be decoded using an optimum quantization code book for the speech segment. Accordingly, natural, high-quality synthetic speech can be generated.

In the second embodiment, the aforementioned speech synthesis algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech synthesis algorithm can also be constituted by hardware.

[First Modification of the Second Embodiment]

In the second embodiment, as in the first embodiment described previously, the number of bits (i.e., the number of quantization steps of scalar quantization) per sample can be changed for each speech segment data. This can be accomplished by changing the procedures of the second embodiment as follows. That is, in the speech segment dictionary formation algorithm, the number of quantization steps is determined prior to the process (the write of the scalar quantization code book) in step S404 of Fig. 4. The determined number of quantization steps and the code book are recorded in the speech segment dictionary 112. In the speech synthesis algorithm, the number of quantization steps is read out from the speech segment dictionary 112 before the process (the read-out of the scalar quantization code book) in step S505. As in the first embodiment, the number

of quantization steps can be determined on the basis of the encoding distortion.

[Second Modification of the Second Embodiment]

In the speech synthesis algorithm of the second embodiment, in step S505 a scalar quantization code book formed for each speech segment data is selected. However, the present invention is not limited to this embodiment. For example, from a plurality of types of scalar quantization code books previously held by the speech segment dictionary 112, a code book having the highest performance (i.e., by which the quantization distortion is a minimum) can also be chosen.

[Third Modification of the Second Embodiment]

In the second embodiment, a quantization code book is so designed that the encoding distortion is a minimum, and speech segment data is scalar-quantized by using the designed quantization code book. However, speech segment data whose encoding distortion is larger than a predetermined threshold value can also be registered in a speech segment dictionary without being encoded. With this arrangement, degradation of the quality of an unstable speech segment (e.g., a speech segment classified into a voiced fricative sound or a plosive) can be prevented. Also, natural, high-quality synthetic speech can be generated by using a speech segment dictionary thus formed.

[Third Embodiment]

A speech segment dictionary formation algorithm and a speech synthesis algorithm according to the second embodiment of the present invention will be described below by using the speech processing apparatus shown in Fig. 1.

In the above second embodiment, one of a plurality of encoding methods using different quantization code books is selected for each speech segment to be registered in a speech segment dictionary 112. In this third embodiment, however, one of a plurality of encoding methods using different quantization code books is selected for each of a plurality of speech segment clusters. Note that a speech segment to be registered in the speech segment dictionary 112 is composed of a phoneme, semi-phoneme, diphone (e.g., CV or VC), VCV (or CVC), or combinations thereof.

(Formation of speech segment dictionary)

Fig. 6 is a flow chart for explaining the speech segment dictionary formation algorithm in the third embodiment of the present invention. A program for achieving this algorithm is stored in a storage device 101. A CPU 100 reads out this program from the storage device 101 on the basis of an instruction from a user and executes the following procedure.

In step S601, the CPU 100 reads out all of N speech segment data (each speech segment data is non-compressed) stored in speech segment database 111 of an external storage device 102. In step S602, the CPU 100 clusters all these

speech segments into a plurality of (M) speech segment clusters. More specifically, the CPU 100 forms M speech segment clusters in accordance with the similarity of the waveform of each speech segment.

In step S603, the CPU 100 initializes index i which indicates each of the M speech segment clusters to "0". In step S604, the CPU 100 forms a scalar quantization code book Qi for ith speech segment cluster Li. In step S605, the CPU 100 writes the code book Qi formed in step S604 into the speech segment dictionary 112.

In step S606, the CPU 100 checks whether the above processing is performed for all of the M speech segment clusters. If i = M - 1 (the processing is completely performed for all of the M speech segment clusters), the flow advances to step S608. If not, in step S607 the CPU 100 adds 1 to the index i, the flow returns to step S604, and the CPU 100 forms a scalar quantization code book for the next speech segment cluster.

After scalar quantization code books are formed for all of the M speech segment clusters, this algorithm advances to step S608. In step S608, the CPU 100 initializes index i, which indicates each of the N speech segments stored in the speech segment database 111 of the external storage device 102, to "0". In step S609, the CPU 100 selects a scalar quantization code book Qi for ith speech segment data Wi. This scalar quantization code book Qi selected is a

quantization code book corresponding to a speech segment cluster to which the speech segment data Wi belongs.

In step S610, the CPU 100 writes information (code book information) designating the scalar quantization code book selected in step S609 and the like into the speech segment dictionary 112. In addition to the code book information, the CPU 100 writes information necessary to decode the speech segment data Wi. In step S611, the CPU 100 encodes the speech segment data Wi by using the code book Qi formed in step S604. In step S612, the CPU 100 writes speech segment data Ci (= {c0, c1,..., cT-1} encoded in step S611 into the speech segment dictionary 112.

In step S613, the CPU 100 checks whether the above processing is performed for all of the N speech segment data. If i = N - 1, the CPU 100 completes this algorithm. If not, in step S614 the CPU 100 adds 1 to the index i, the flow returns to step S609, and the CPU 100 forms a scalar quantization code book for the next speech segment data.

In the speech segment dictionary formation algorithm of the third embodiment as described above, one of a plurality of encoding methods using different quantization code books can be selected for each of a plurality of speech segment clusters. This can reduce the number of quantization code books to be registered in the speech segment dictionary 112. With this arrangement, a storage capacity necessary for the speech segment dictionary can be very efficiently reduced

without deteriorating the quality of speech segments to be registered in the speech segment dictionary. Also, a larger number of types of speech segments than in conventional speech segment dictionaries can be registered in a speech segment dictionary having a storage capacity equivalent to those of the conventional dictionaries.

In the third embodiment, the aforementioned speech segment dictionary formation algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech segment dictionary formation algorithm can also be constituted by hardware.

(Speech synthesis)

Fig. 8 is a flow chart for explaining the speech synthesis algorithm in the third embodiment of the present invention. A program for achieving this algorithm is stored in the storage device 101. The CPU 100 reads out this program on the basis of an instruction from a user and executes the following procedure. For the sake of simplicity, in this embodiment it is assumed that code books corresponding to all speech segment clusters are previously stored in the storage device 101.

Steps S801 to 803 have the same functions and processes as in steps S501 to S503 of Fig. 5, so a detailed description thereof will be omitted.

In step S804, the CPU 100 obtains an optimum speech segment sequence on the basis of a speech segment sequence

obtained in step S802 and prosody determined in step S803. The CPU 100 selects one speech segment contained in this speech segment sequence and retrieves code book information and speech segment data corresponding to the selected speech segment. If the speech segment dictionary 112 is stored in a storage medium such as a hard disk, the CPU 100 sequentially seeks to storage areas of code book information and speech segment data. If the speech segment dictionary 112 is stored in a storage medium such as a RAM, the CPU 100 sequentially moves a pointer (address register) to storage areas of code book information and speech segment data.

In step S805, the CPU 100 reads out the code book information retrieved in step S804 and determines a speech segment cluster of this speech segment data and a scalar quantization code book corresponding to the speech segment cluster. In step S806, the CPU 100 looks up the speech segment dictionary 112 to obtain the scalar quantization code book determined in step S805. In step S807, the CPU 100 reads out the speech segment data retrieved in step S804 from the speech segment dictionary 112. In step S808, the CPU 100 decodes the speech segment data read out in step S807 by using the scalar quantization code book obtained in step S806.

In step S809, the CPU 100 checks whether speech segment data corresponding to all speech segments contained in the speech segment sequence obtained in step S804 are decoded. If all speech segment data are decoded, the flow advances

to step S810. If speech segment data not decoded yet is present, the flow returns to step S804 to decode the next speech segment data.

In step S810, on the basis of the prosody determined in step S803, the CPU 100 modifies and connects the decoded speech segments (i.e., edits the waveform). In step S811, the CPU 100 outputs the synthetic speech obtained in step S810 from the loudspeaker of an output device 103.

In the speech synthesis algorithm of the third embodiment as described above, a desired speech segment can be decoded using an optimum quantization code book for a speech segment cluster to which this speech segment belongs. Accordingly, natural, high-quality synthetic speech can be generated.

In the third embodiment, the aforementioned speech synthesis algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech synthesis algorithm can also be constituted by hardware.

[First Modification of the Third Embodiment]

In the speech segment dictionary formation algorithm of the third embodiment, the procedure of forming a speech segment cluster in accordance with the similarity of the waveform of a speech segment has been explained. However, it is also possible to form a speech segment cluster in accordance with the type (e.g., a voiced fricative sound,

plosive, nasal sound, some other voiced sound, or unvoiced sound) of speech segment, and form a quantization code book for each speech segment cluster.

[Second Modification of the Third Embodiment]

In the speech synthesis algorithm of the third embodiment, in step S805 a scalar quantization code book formed for each speech segment cluster is selected. However, the present invention is not limited to this embodiment. For example, from a plurality of types of scalar quantization code books held by the speech segment dictionary 112, a code book having the highest performance (i.e., by which the quantization distortion is a minimum) can also be chosen.

[Third Modification of the Third Embodiment]

In the third embodiment, scalar quantization can also be performed by taking the gain (power) into consideration. That is, in step 609 a gain $\underline{g}$ of speech segment data is obtained prior to selecting a scalar quantization code book. In step S610, the obtained gain $\underline{g}$ and code book information are written in the speech segment dictionary 112. In step S611, quantization is performed by taking account of the gain $\underline{g}$. This means that equation (3) presented earlier is replaced by

$$ct = \text{argn min } (xt - g \cdot qn)^2 \quad (0 \leqq n < N)$$

Meanwhile, in step S808 (reference to a code book) of the speech synthesis algorithm, the value $\underline{q}$ obtained by the

code book reference is multiplied by the gain g to yield a decoded value.

[Fourth Modification of the Third Embodiment]

In the third embodiment, an optimum quantization code book is designed for each speech segment cluster, and speech segment data belonging to each speech segment cluster is scalar-quantized by using the designed quantization code book. However, speech segment data found to increase the encoding distortion can also be registered in a speech segment dictionary without being encoded. With this arrangement, degradation of the quality of an unstable speech segment (e.g., a speech segment classified into a voiced fricative sound or a plosive) can be prevented. Also, natural, high-quality synthetic speech can be generated by using a speech segment dictionary thus formed.

[Fourth Embodiment]

A speech segment dictionary formation algorithm and a speech synthesis algorithm according to the fourth embodiment of the present invention will be described below by using the speech processing apparatus shown in Fig. 1.

In the fourth embodiment, a linear prediction coefficient and a prediction difference are calculated for each speech segment data, and the data is encoded by an optimum quantization code book for the calculated prediction difference. Note that a speech segment to be registered in the speech segment dictionary 112 is composed of a phoneme,

semi-phoneme, diphone (e.g., CV or VC), VCV (or CVC), or combinations thereof.

(Formation of speech segment dictionary)

Fig. 9 is a flow chart for explaining the speech segment dictionary formation algorithm in the fourth embodiment of the present invention. A program for achieving this algorithm is stored in a storage device 101. A CPU 100 reads out this program from the storage device 101 on the basis of an instruction from a user and executes the following procedure.

In step S901, the CPU 100 initializes an index i, which indicates each of N speech segment data (each speech segment data is non-compressed) stored in speech segment database 111 of an external storage device 102, to "0". In step S902, the CPU 100 reads out speech segment data (a speech segment before encoding) Wi of the ith speech segment indicated by this index i. Assume that the readout data Wi is

$$Wi = \{x0, x1, \ldots, xT-1\}$$

where T is the time length (in units of samples) of Wi.

In step S903, the CPU 100 calculates a linear prediction coefficient and a prediction difference of the speech segment data Wi read out in step S902. Assuming the linear prediction order is order L, this linear prediction model is represented by using a linear prediction coefficient al and a prediction difference dt as

$$xt = \Sigma alxt-1 + dt \qquad \ldots(4)$$

where Σ is the summation of l = 1 to L.

Hence, the linear prediction coefficient al which minimizes the square-sum of the prediction difference dt

$$\Sigma dt^2 \quad \ldots(5)$$

is determined. In this expression, Σ is the summation of t = 1 to T - 1.

In step S904, the CPU 100 writes the linear prediction coefficient al calculated in step S903 into the speech segment dictionary 112. In step S905, the CPU 100 forms a quantization code book Qi of the prediction difference dt calculated in step S903. More specifically, the CPU 100 decodes the encoded prediction difference dt by using the quantization code book Qi and so designs that a mean square error ρ of decoded data sequence Ei = {el, el+1,..., eT-1} is a minimum (i.e., the encoding distortion is a minimum). In this case, an algorithm such as an LBG method is usable. With this arrangement, the distortion of the waveform of a speech segment produced by encoding can be minimized. Note that the mean square error ρ can be represented by

$$\rho = (1/T) \cdot \Sigma (dt - et)^2 \quad \ldots(6)$$

where "Σ" is the summation of t = 0 to T - 1.

In step S906, the CPU 100 writes the quantization code book Qi formed in step S905 and the like in the speech segment dictionary 112. In addition to the code book Qi, the CPU 100 writes information necessary to decode the speech segment data Wi. In step S907, the CPU 100 encodes the speech segment

data Wi by linear predictive coding by using the linear prediction coefficient al calculated in step S903 and the code book Qi formed in step S905. Assuming the code book Qi is

$$Qi = \{q0, q1, \ldots, qN-1\} \quad (N \text{ is the quantization step}),$$

a code ct corresponding to xt ($\in$Wi) can be represented by

$$ct = \text{argn min } (xt - \Sigma alyt-1 - qn)^2 \quad (0 \leqq n < N) \qquad \ldots(7)$$

where yt is the value obtained by encoding and then decoding xt by this method.

In step S908, the CPU 100 writes speech segment data Ci (= {c0, c1,..., cT-1} encoded in step S907 into the speech segment dictionary 112. In step S909, the CPU 100 checks whether the above processing is performed for all of the N speech segment data. If i = N - 1, the CPU 100 completes this algorithm. If not, in step S910 the CPU 100 adds 1 to the index i, the flow returns to step S902, and the CPU 100 reads out speech segment data designated by the updated index i. The CPU 100 repeatedly executes this processing for all of the N speech segment data.

In the speech segment dictionary formation algorithm of the fourth embodiment as described above, it is possible to calculate a linear prediction coefficient and a prediction difference for each speech segment to be registered in the speech segment dictionary 112, and encode the speech segment by an optimum quantization code book for the calculated

prediction difference. With this arrangement, a storage capacity necessary for the speech segment dictionary can be very efficiently reduced without deteriorating the quality of speech segments to be registered in the speech segment dictionary. Also, a larger number of types of speech segments than in conventional speech segment dictionaries can be registered in a speech segment dictionary having a storage capacity equivalent to those of the conventional dictionaries.

In the fourth embodiment, the aforementioned speech segment dictionary formation algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech segment dictionary formation algorithm can also be constituted by hardware.

(Speech synthesis)

Fig. 10 is a flow chart for explaining the speech synthesis algorithm in the fourth embodiment of the present invention. A program for achieving this algorithm is stored in the storage device 101. The CPU 100 reads out this program on the basis of an instruction from a user and executes the following procedure.

In step S1001, the user inputs a character string in Japanese, English, or some other language by using the keyboard and the mouse of an input device 104. In the case of Japanese, the user inputs a character string expressed by kana-kanji mixed text. In step S1002, the CPU 100 analyzes

the input character string and obtains the speech segment sequence of this character string and parameters for determining the prosody of this character string. In step S1003, on the basis of the prosodic parameters obtained in step S1002, the CPU 100 determines prosody such as a duration length (the prosody for controlling the length of a voice), the fundamental frequency (the prosody for controlling the pitch of a voice), and the power (the prosody for controlling the strength of a voice).

In step S1004, the CPU 100 obtains an optimum speech segment sequence on the basis of the speech segment sequence obtained in step S1002 and the prosody determined in step S1003. The CPU 100 selects one speech segment contained in this speech segment sequence and retrieves a linear prediction coefficient, quantization code book, and prediction difference corresponding to the selected speech segment. If the speech segment dictionary 112 is stored in a storage medium such as a hard disk, the CPU 100 sequentially seeks to storage areas of linear prediction coefficients, quantization code books, and prediction differences. If the speech segment dictionary 112 is stored in a storage medium such as a RAM, the CPU 100 sequentially moves a pointer (address register) to storage areas of linear prediction coefficients, quantization code books, and prediction differences.

In step S1005, the CPU 100 reads out the prediction coefficient retrieved in step S1004 from the speech segment dictionary 112. In step S1006, the CPU 100 reads out the quantization code book retrieved in step S1004 from the speech segment dictionary 112. In step S1007, the CPU 100 reads out the prediction difference retrieved in step S1004 from the speech segment dictionary 112. In step S1008, the CPU 100 decodes the prediction difference by using the prediction coefficient, the quantization code book, and the decoded data of the immediately preceding sample, thereby obtaining speech segment data.

In step S1009, the CPU 100 checks whether speech segment data corresponding to all speech segments contained in the speech segment sequence obtained in step S1004 are decoded. If all speech segment data are decoded, the flow advances to step S1010. If speech segment data not decoded yet is present, the flow returns to step S1004 to decode the next speech segment data.

In step S1010, on the basis of the prosody determined in step S1003, the CPU 100 modifies and connects the decoded speech segments (i.e., edits the waveform). In step S1011, the CPU 100 outputs the synthetic speech obtained in step S1010 from the loudspeaker of an output device 103.

In the speech synthesis algorithm of the fourth embodiment as described above, a desired speech segment can be decoded using an optimum quantization code book for the

speech segment. Accordingly, natural, high-quality synthetic speech can be generated.

In the fourth embodiment, the aforementioned speech synthesis algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech synthesis algorithm can also be constituted by hardware.

[First Modification of the Fourth Embodiment]

In the fourth embodiment, as in the first embodiment described earlier, the number of bits (i.e., the number of quantization steps) per sample can be changed for each speech segment data. This can be accomplished by changing the procedures of the fourth embodiment as follows. That is, in the speech segment dictionary formation algorithm, the number of quantization steps is determined prior to the process (the write of the quantization code book) in step S905. The determined number of quantization steps and the code book are recorded in the speech segment dictionary 112. In the speech synthesis algorithm, the number of quantization steps is read out from the speech segment dictionary 112 before the process (the read-out of the quantization code book) in step S1006. As in the first embodiment, the number of quantization steps can be determined on the basis of the encoding distortion.

[Second Modification of the Fourth Embodiment]

In the fourth embodiment, the linear prediction order L can also be change for each speech segment data. This can be accomplished by changing the procedures of the fourth embodiment as follows. That is, in the speech segment dictionary formation algorithm, the prediction order is set prior to the process (the write of the prediction coefficient) in step S904. The set prediction order and the prediction coefficient are recorded in the speech segment dictionary 112. In the speech synthesis algorithm, the prediction order is read out from the speech segment dictionary 112 before the process (the read-out of the prediction coefficient) in step S1005. As in the first embodiment, this prediction order can be determined on the basis of the encoding distortion.

[Third Modification of the Fourth Embodiment]

In the fourth embodiment, the encoding performance of the quantization code book formed in step S905 can be further improved. This is so because while in step S905 the code book is optimized for the prediction difference dt, in step S907 the quantization code book is referred to with respect to

$$xt - \Sigma alyt-1 \quad (\neq dt = xt - \Sigma alxt-1) \quad ...(8)$$

An AbS (Analysis by Synthesis) method or the like can be used as an algorithm for updating this code book. In this expression, Σ is the summation of $l = 1$ to L.

[Fourth Modification of the Fourth Embodiment]

In the fourth embodiment, one quantization code book is designed for one speech segment data. However, one quantization code book can also be designed for a plurality of speech segment data. For example, as in the third embodiment, it is possible to cluster N speech segment data into M speech segment clusters and design a quantization code book for each speech segment cluster.

[Fifth Modification of the Fourth Embodiment]

In the fourth embodiment, data of L samples from the beginning of speech segment data can be directly written in the speech segment dictionary 112 without being encoded. This makes it possible to avoid a phenomenon in which linear prediction cannot be well performed for L samples from the beginning of speech segment data.

[Sixth Modification of the Fourth Embodiment]

In the fourth embodiment, in step S907 the code ct that is optimum for xt is obtained. However, this optimum code ct can also be obtained by taking account of m samples after xt. This can be realized by temporarily determining the code ct and recursively searching for the code ct (searching the tree structure).

[Seventh Modification of the Fourth Embodiment]

In the fourth embodiment, a quantization code book is so designed that the encoding distortion is a minimum, and speech segment data is linearly encoded by using the designed quantization code book. However, speech segment data whose

encoding distortion is larger than a predetermined threshold value can be registered in a speech segment dictionary without being encoded. With this arrangement, degradation of the quality of an unstable speech segment (e.g., a speech segment classified into a voiced fricative sound or a plosive) can be prevented. Also, natural, high-quality synthetic speech can be generated by using a speech segment dictionary thus formed.

[Fifth Embodiment]

A speech segment dictionary formation algorithm and a speech synthesis algorithm according to the fifth embodiment of the present invention will be described below by using the speech processing apparatus shown in Fig. 1.

In the fifth embodiment, the various encoding schemes used in the previous embodiments are combined, and an optimum encoding method is selected for each speech segment data to be registered in a speech segment dictionary 112. In this fifth embodiment, an unstable speech segment (e.g., a speech segment classified into a voiced fricative sound or a plosive) is processed without being compressed. Note that a speech segment to be registered in the speech segment dictionary 112 is composed of a phoneme, semi-phoneme, diphone (e.g., CV or VC), VCV (or CVC), or combinations thereof.

(Formation of speech segment dictionary)

Fig. 11 is a flow chart for explaining the speech segment dictionary formation algorithm in the fifth embodiment of the present invention. A program for achieving this algorithm is stored in a storage device 101. A CPU 100 reads out this program from the storage device 101 on the basis of an instruction from a user and executes the following procedure.

In step S1101, the CPU 100 initializes an index $\underline{i}$, which indicates each of N speech segment data (each speech segment data is non-compressed) stored in speech segment database 111 of an external storage device 102, to "0". Note that this index $\underline{i}$ is stored in the storage device 101.

In step S1102, the CPU 100 reads out ith speech segment data Wi indicated by this index $\underline{i}$. Assume that the readout data Wi is

$$Wi = \{x0, x1, \ldots, xT-1\}$$

where T is the time length (in units of samples) of Wi.

In step S1103, the CPU 100 encodes the speech segment data Wi read out in step S1102 by using the encoding scheme (i.e., linear predictive coding) explained in the fourth embodiment.

In step S1104, the CPU 100 calculates encoding distortion ρ by this encoding scheme. In step S1105, the CPU 100 checks whether the encoding distortion ρ calculated in step S1104 is larger than a predetermined threshold value $\rho 0$. If $\rho > \rho 0$, the flow advances to step S1108, and the

CPU 100 encodes the speech segment data Wi by using another encoding scheme. If $\rho > \rho 0$ does not hold, the flow advances to step S1106.

In step S1106, the CPU 100 writes encoding information of the speech segment data Wi in the speech segment dictionary 112. This encoding information contains information specifying the encoding method by which the speech segment data Wi is encoded and information necessary to decode the speech segment data Wi (e.g., a prediction coefficient and a quantization code book). In step S1107, the CPU 100 writes the speech segment data Wi encoded in step S1103 into the speech segment dictionary 112, and the flow advances to step S1120.

On the other hand, in step S1108 the CPU 100 encodes the speech segment data Wi read out in step S1102 by using the encoding scheme (i.e., the 7-bit μ-law scheme or the 8-bit μ-law scheme) explained in the first embodiment.

In step S1109, the CPU 100 calculates encoding distortion ρ by this encoding scheme. In step S1110, the CPU 100 checks whether the encoding distortion ρ calculated in step S1109 is larger than a predetermined threshold value $\rho 1$. If $\rho > \rho 1$, the flow advances to step S1113, and the CPU 100 encodes the speech segment data Wi by using another encoding scheme. If $\rho > \rho 1$ does not hold, the flow advances to step S1111.

In step S1111, the CPU 100 writes encoding information of the speech segment data Wi in the speech segment dictionary 112. This encoding information contains information specifying the encoding method by which the speech segment data Wi is encoded and information necessary to decode the speech segment data Wi. In step S1112, the CPU 100 writes the speech segment data Wi encoded in step S1108 into the speech segment dictionary 112, and the flow advances to step S1120.

On the other hand, in step S1113 the CPU 100 encodes the speech segment data Wi read out in step S1102 by using the encoding scheme (i.e., scalar quantization) explained in the second or third embodiment.

In step S1114, the CPU 100 calculates encoding distortion ρ by this encoding scheme. In step S1115, the CPU 100 checks whether the encoding distortion ρ calculated in step S1114 is larger than a predetermined threshold value $\rho 2$. For example, the waveform of a strongly unstable speech segment (e.g., a speech segment classified into a voiced fricative sound or a plosive) largely varies, so $\rho > \rho 2$ does not hold. If $\rho > \rho 2$, the flow advances to step S1118. If $\rho > \rho 2$ does not hold, the flow advances to step S1116.

In step S1116, the CPU 100 writes encoding information of the speech segment data Wi in the speech segment dictionary 112. This encoding information contains information specifying the encoding method by which the speech segment

data Wi is encoded and information necessary to decode the speech segment data Wi (e.g., a quantization code book). In step S1117, the CPU 100 writes the speech segment data Wi encoded in step S1113 into the speech segment dictionary 112, and the flow advances to step S1120.

On the other hand, in step S1118 the CPU 100 writes encoding information of the speech segment data Wi read out in step S1102 into the speech segment dictionary 112 without compressing the speech segment data Wi. This encoding information contains information indicating that the speech segment data Wi is not encoded. In step S1119, the CPU 100 writes this speech segment data Wi in the speech segment dictionary 112, and the flow advances to step S1120. With this arrangement, deterioration of the quality of an unstable speech segment can be prevented.

In step S1120, the CPU 100 checks whether the above processing is performed for all of the N speech segment data. If i = N - 1, the CPU 100 completes this algorithm. If not, in step S1121 the CPU 100 adds 1 to the index i, the flow returns to step S1102, and the CPU 100 reads out speech segment data designated by the updated index i. The CPU 100 repeatedly executes this processing for all of the N speech segment data.

In the speech segment dictionary formation algorithm of the fifth embodiment as described above, an encoding scheme can be selected from the μ-law scheme, scalar

quantization, and linear predictive coding for each speech segment to be registered in the speech segment dictionary 112. With this arrangement, a storage capacity necessary for the speech segment dictionary can be very efficiently reduced without deteriorating the quality of speech segments to be registered in the speech segment dictionary. Also, a larger number of types of speech segments than in conventional speech segment dictionaries can be registered in a speech segment dictionary having a storage capacity equivalent to those of the conventional dictionaries.

In the fifth embodiment, the aforementioned speech segment dictionary formation algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech segment dictionary formation algorithm can also be constituted by hardware.

(Speech synthesis)

Fig. 12 is a flow chart for explaining the speech synthesis algorithm in the fifth embodiment of the present invention. A program for achieving this algorithm is stored in the storage device 101. The CPU 100 reads out this program on the basis of an instruction from a user and executes the following procedure.

In step S1201, the user inputs a character string in Japanese, English, or some other language by using the keyboard and the mouse of an input device 104. In the case of Japanese, the user inputs a character string expressed

by kana-kanji mixed text. In step S1202, the CPU 100 analyzes the input character string and obtains the speech segment sequence of this character string and parameters for determining the prosody of this character string. In step S1203, on the basis of the prosodic parameters obtained in step S1202, the CPU 100 determines prosody such as a duration length (the prosody for controlling the length of a voice), fundamental frequency (the prosody for controlling the pitch of a voice), and power (the prosody for controlling the strength of a voice).

In step S1204, the CPU 100 obtains an optimum speech segment sequence on the basis of the speech segment sequence obtained in step S1202 and the prosody determined in step S1203. The CPU 100 selects one speech segment contained in this speech segment sequence and retrieves speech segment data and encoding information corresponding to the selected speech segment. If the speech segment dictionary 112 is stored in a storage medium such as a hard disk, the CPU 100 sequentially seeks to storage areas of speech segment data and encoding information. If the speech segment dictionary 112 is stored in a storage medium such as a RAM, the CPU 100 sequentially moves a pointer (address register) to storage areas of speech segment data and encoding information.

In step S1205, the CPU 100 reads out the encoding information retrieved in step S1204 from the speech segment dictionary 112. In step S1206, the CPU 100 reads out the

speech segment data retrieved in step S1204 from the speech segment dictionary 112.

In step S1207, on the basis of the encoding information read out in step S1205, the CPU 100 checks whether the speech segment data read out in step S1206 is encoded. If the data is encoded, the flow advances to step S1208 to specify the encoding method. If the data is not encoded, the flow advances to step S1215.

In step S1208, on the basis of the encoding information read out in step S1205, the CPU 100 examines the encoding method of the speech segment data read out in step S1206. If the encoding method is linear predictive coding, the flow advances to step S1212 to decode the data. In other cases, the flow advances to step S1209.

In step S1209, on the basis of the encoding information read out in step S1205, the CPU 100 examines the encoding method of the speech segment data read out in step S1206. If the encoding method is the μ-law scheme, the flow advances to step S1213 to decode the data. In other cases, the flow advances to step S1210.

In step S1210, on the basis of the encoding information read out in step S1205, the CPU 100 examines the encoding method of the speech segment data read out in step S1206. If the encoding method is scalar quantization, the flow advances to step S1214 to decode the data. In other cases, the flow advances to step S1211.

In step S1211, the CPU 100 checks whether speech segment data corresponding to all speech segments contained in the speech segment sequence obtained in step S1204 are decoded. If all speech segment data are decoded, the flow advances to step S1215. If speech segment data not decoded yet is present, the flow returns to step S1204 to decode the next speech segment data.

In step S1215, on the basis of the prosody determined in step S1203, the CPU 100 modifies and connects the decoded speech segments (i.e., edits the waveform). In step S1216, the CPU 100 outputs the synthetic speech obtained in step S1215 from the loudspeaker of an output device 103.

In the speech synthesis algorithm of the fifth embodiment as described above, a desired speech segment can be decoded by a decoding method corresponding to one of the μ-law scheme, scalar quantization, and linear predictive coding. Therefore, natural, high-quality synthetic speech can be generated.

In the fifth embodiment, the aforementioned speech synthesis algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech synthesis algorithm can also be constituted by hardware.

[Sixth Embodiment]

A speech segment dictionary formation algorithm and a speech synthesis algorithm according to the sixth

embodiment of the present invention will be described below by using the speech processing apparatus shown in Fig. 1.

In the above fifth embodiment, an optimum encoding method is selected from a plurality of encoding methods using different encoding schemes for each speech segment data to be registered in a speech segment dictionary 112. In the sixth embodiment, however, an optimum encoding method is chosen from a plurality of encoding methods using different encoding schemes in accordance with the type of speech segment data. Note that a speech segment to be registered in the speech segment dictionary 112 is constructed of a phoneme, semi-phoneme, diphone (e.g., CV or VC), VCV (or CVC), or combinations thereof.

(Formation of speech segment dictionary)

Fig. 13 is a flow chart for explaining the speech segment dictionary formation algorithm in the sixth embodiment of the present invention. A program for achieving this algorithm is stored in a storage device 101. A CPU 100 reads out this program from the storage device 101 on the basis of an instruction from a user and executes the following procedure.

In step S1301, the CPU 100 initializes an index i, which indicates each of N speech segment data (each speech segment data is non-compressed) stored in speech segment database 111 of an external storage device 102, to "0". Note that this index i is stored in the storage device 101.

In step S1302, the CPU 100 reads out ith speech segment data Wi indicated by this index i. Assume that the readout data Wi is

Wi = {x0, x1,..., xT-1}

where T is the time length (in units of samples) of Wi.

In step S1303, the CPU 100 discriminates the type of the speech segment data Wi read out in step S1302. More specifically, the CPU 100 checks whether the type of the speech segment data Wi is a voiced fricative sound, plosive, unvoiced sound, nasal sound, or some other voiced sound.

If the type of the speech segment data Wi is a voiced fricative sound or plosive, the flow advances to step S1316. In step S1316, the CPU 100 does not compress this speech segment data Wi. With this arrangement, degradation of the quality of the voiced fricative sound or plosive can be prevented. In step S1316, the CPU 100 writes encoding information of the speech segment data Wi in the speech segment dictionary 112. This encoding information contains the type of the speech segment data Wi and information indicating that the speech segment data Wi is not encoded. In step S1317, the CPU 100 writes the speech segment data Wi in the speech segment dictionary 112 without encoding the speech segment data Wi, and the flow advances to step S1318.

If the type of the speech segment data is an unvoiced sound, the flow advances to step S1306. In step S1306, the CPU 100 encodes the speech segment data Wi by using the

encoding scheme (i.e., scalar quantization) explained in the second or third embodiment. In step S1307, the CPU 100 writes encoding information of the speech segment data Wi in the speech segment dictionary 112. This encoding information contains the type of the speech segment data Wi, information specifying the encoding method by which the speech segment data Wi is encoded, and information necessary to decode the speech segment data Wi (e.g., a quantization code book). In step S1308, the CPU 100 writes the speech segment data Wi encoded in step S1306 into the speech segment dictionary 112, and the flow advances to step S1318.

If the type of the speech segment data is a nasal sound, the flow advances to step S1310. In step S1310, the CPU 100 encodes the speech segment data Wi by using the encoding scheme (i.e., linear predictive coding) explained in the fourth embodiment. In step S1311, the CPU 100 writes encoding information of the speech segment data Wi in the speech segment dictionary 112. This encoding information contains the type of the speech segment data Wi, information specifying the encoding method by which the speech segment data Wi is encoded, and information necessary to decode the speech segment data Wi (e.g., a prediction coefficient and a quantization code book). In step S1312, the CPU 100 writes the speech segment data Wi encoded in step S1310 into the speech segment dictionary 112, and the flow advances to step S1318.

If the type of the speech segment data Wi is some other voiced sound, the flow advances to step S1313. In step S1313, the CPU 100 encodes the speech segment data Wi by using the encoding scheme (i.e., the 7-bit μ-law scheme or the 8-bit μ-law scheme) explained in the first embodiment. In step S1314, the CPU 100 writes encoding information of the speech segment data Wi in the speech segment dictionary 112. This encoding information contains the type of the speech segment data Wi, information specifying the encoding method by which the speech segment data Wi is encoded, and information necessary to decode the speech segment data Wi. In step S1315, the CPU 100 writes the speech segment data Wi encoded in step S1313 into the speech segment dictionary 112, and the flow advances to step S1318.

In step S1318, the CPU 100 checks whether the above processing is performed for all of the N speech segment data. If i = N - 1, the CPU 100 completes this algorithm. If not, in step S1319 the CPU 100 adds 1 to the index i, the flow returns to step S1302, and the CPU 100 reads out speech segment data designated by the updated index i. The CPU 100 repeatedly executes this processing for all of the N speech segment data.

In the speech segment dictionary formation algorithm of the sixth embodiment as described above, an encoding scheme can be selected from the μ-law scheme, scalar quantization, and linear predictive coding in accordance

with the type of speech segment to be registered in the speech segment dictionary 112. With this arrangement, a storage capacity necessary for the speech segment dictionary can be very efficiently reduced without deteriorating the quality of speech segments to be registered in the speech segment dictionary. Also, a larger number of types of speech segments than in conventional speech segment dictionaries can be registered in a speech segment dictionary having a storage capacity equivalent to those of the conventional dictionaries.

In the sixth embodiment, the aforementioned speech segment dictionary formation algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech segment dictionary formation algorithm can also be constituted by hardware.

(Speech synthesis)

Fig. 14 is a flow chart for explaining the speech synthesis algorithm in the sixth embodiment of the present invention. A program for achieving this algorithm is stored in the storage device 101. The CPU 100 reads out this program on the basis of an instruction from a user and executes the following procedure.

Steps S1401 to S1403 have the same functions and processes as in steps S1201 to S1203 of Fig. 12, so a detailed description thereof will be omitted.

In step S1404, the CPU 100 obtains an optimum speech segment sequence on the basis of a speech segment sequence obtained in step S1402 and prosody determined in step S1403. The CPU 100 selects one speech segment contained in this speech segment sequence and retrieves speech segment data and encoding information corresponding to the selected speech segment. If the speech segment dictionary 112 is stored in a storage medium such as a hard disk, the CPU 100 sequentially seeks to storage areas of speech segment data and encoding information. If the speech segment dictionary 112 is stored in a storage medium such as a RAM, the CPU 100 sequentially moves a pointer (address register) to storage areas of speech segment data and encoding information.

In step S1405, the CPU 100 reads out the encoding information retrieved in step S1404 from the speech segment dictionary 112. In step S1406, the CPU 100 reads out the speech segment data retrieved in step S1404 from the speech segment dictionary 112.

In step S1406, on the basis of the encoding information read out in step S1405, the CPU 100 discriminates the type of the speech segment data retrieved in step S1404. More specifically, the CPU 100 checks whether the type of the speech segment data is a voiced fricative sound, plosive, unvoiced sound, nasal sound, or some other voiced sound.

If the type of the speech segment data is a voiced fricative sound or plosive, the flow advances to step S1416.

In step S1416, the CPU 100 reads out the speech segment data retrieved in step S1404, and the flow advances to step S1417. In this case, this speech segment data is not encoded.

If the type of the speech segment data is an unvoiced sound, the flow advances to step S1414. In step S1414, the CPU 100 reads out the speech segment data retrieved in step S1404, and the flow advances to step S1415. This speech segment data is encoded by scalar quantization. In step S1415, the CPU 100 decodes this speech segment data on the basis of the encoding information read out in step S1405.

If the type of the speech segment data is a nasal sound, the flow advances to step S1412. In step S1412, the CPU 100 reads out the speech segment data retrieved in step S1404, and the flow advances to step S1413. This speech segment data is encoded by linear predictive coding. In step S1413, the CPU 100 decodes this speech segment data on the basis of the encoding information read out in step S1405.

If the type of the speech segment data is some other voiced sound, the flow advances to step S1410. In step S1410, the CPU 100 reads out the speech segment data retrieved in step S1404, and the flow advances to step S1411. This speech segment data is encoded by the μ-law scheme. In step S1411, the CPU 100 decodes this speech segment data on the basis of the encoding information read out in step S1405.

In step S1417, the CPU 100 checks whether speech segment data corresponding to all speech segments contained

in the speech segment sequence obtained in step S1404 are decoded. If all speech segment data are decoded, the flow advances to step S1418. If speech segment data not decoded yet is present, the flow returns to step S1404 to decode the next speech segment data.

In step S1418, on the basis of the prosody determined in step S1403, the CPU 100 modifies and connects the decoded speech segments (i.e., edits the waveform). In step S1419, the CPU 100 outputs the synthetic speech obtained in step S1418 from the loudspeaker of an output device 103.

In the speech synthesis algorithm of the sixth embodiment as described above, a desired speech segment can be decoded by a decoding method corresponding to one of the μ-law scheme, scalar quantization, and linear predictive coding. With this arrangement, natural, high-quality synthetic speech can be generated.

In the sixth embodiment, the aforementioned speech synthesis algorithm is realized on the basis of the program stored in the storage device 101. However, a part or the whole of this speech synthesis algorithm can also be constituted by hardware.

[Other Embodiments]

In the second, fourth, and fifth embodiments described above, scalar quantization is used as the method of quantization. However, vector quantization can also be

applied by regarding a plurality of consecutive samples as one vector.

Also, it is possible to divide an unstable speech segment such as a plosive into two portions before and after the plosion and encode these two portions by their respective optimum encoding methods. This can further improve the encoding efficiency of an unstable speech segment.

The fourth embodiment has been explained on the basis of a linear prediction model. However, some other vocal cord filter model is also applicable. For example, an LMA (Log Magnitude Approximation) filter coefficient can be used in place of a linear prediction coefficient, and model parameters can be calculated by using the residual error of this LMA filter instead of a prediction difference. With this arrangement, the fourth embodiment can be applied to the cepstrum domain.

Each of the above embodiments is applicable to a system comprising a plurality of devices (e.g., a host computer, interface device, reader, and printer) or to an apparatus (e.g., a copying machine or facsimile apparatus) comprising a single device.

In each of the above embodiments, on the basis of instructions by program codes read out by the CPU 100, an operating system (OS) or the like running on the CPU 100 can execute a part or the whole of actual processing.

Furthermore, in each of the above embodiments, program codes read out from the storage device 101 are written in a memory of a function extension unit connected to the CPU 100, and a CPU or the like of this function extension unit executes a part or the whole of actual processing on the basis of instructions by the program codes.

In each of the embodiments as described above, an encoding method can be selected for each speech segment data. Therefore, a storage capacity necessary for the speech segment dictionary can be very efficiently reduced without deteriorating the quality of speech segments to be registered in the speech segment dictionary. Also, natural, high-quality synthetic speech can be generated by using the speech segment dictionary thus formed.

The present invention is not limited to the above embodiments and various changes and modifications can be made within the spirit and scope of the present invention. Therefore, to apprise the public of the scope of the present invention, the following claims are made.

WHAT IS CLAIMED IS:

1. A speech information processing method of generating a speech segment dictionary for holding a plurality of speech segments, comprising:

a selection step of selecting an encoding method of encoding a speech segment from a plurality of encoding methods;

a encoding step of encoding the speech segment by using the selected encoding method; and

a storage step of storing the encoded speech segment in a speech segment dictionary.

2. The method according to claim 1, wherein one of the plurality of encoding methods differs from other encoding methods in the number of quantization steps.

3. The method according to claim 1, wherein one of the plurality of encoding methods differs from other encoding methods in a quantization code book.

4. The method according to claim 1, wherein one of the plurality of encoding methods differs from other encoding methods in an encoding scheme.

5. The method according to claim 1, wherein one of the plurality of encoding methods uses one of a μ-law scheme, scalar quantization, and linear predictive coding.

6. The method according to claim 1, wherein said selection step comprises performing control such that some speech segments are not encoded.

7. A speech information processing apparatus for generating a speech segment dictionary for holding a plurality of speech segments, comprising:

selecting means for selecting an encoding method of encoding a speech segment from a plurality of encoding methods;

encoding means for encoding the speech segment by using the selected encoding method; and

storage means for storing the encoded speech segment in a speech segment dictionary.

8. The apparatus according to claim 7, wherein one of the plurality of encoding methods differs from other encoding methods in the number of quantization steps.

9. The apparatus according to claim 7, wherein one of the plurality of encoding methods differs from other encoding methods in a quantization code book.

10. The apparatus according to claim 7, wherein one of the plurality of encoding methods differs from other encoding methods in an encoding scheme.

11. The apparatus according to claim 7, wherein one of the plurality of encoding methods uses one of a μ-law scheme, scalar quantization, and linear predictive coding.

12. The apparatus according to claim 7, wherein said selecting means performs control such that some speech segments are not encoded.

13. A speech information processing method of synthesizing speech by using a speech segment dictionary for holding a plurality of speech segments, comprising:

a selection step of selecting, from a plurality of decoding methods, a decoding method of decoding a speech segment read out from the speech segment dictionary;

a decoding step of decoding the speech segment by using the selected decoding method; and

a speech synthesizing step of synthesizing speech on the basis of the decoded speech segment.

14. The method according to claim 13, wherein one of the plurality of decoding methods differs from other decoding methods in the number of quantization steps.

15. The method according to claim 13, wherein one of the plurality of decoding methods differs from other decoding methods in a quantization code book.

16. The method according to claim 13, wherein one of the plurality of decoding methods differs from other decoding methods in a decoding scheme.

17. The method according to claim 13, wherein one of the plurality of decoding methods uses one of a μ-law scheme, scalar quantization, and linear predictive coding.

18. The method according to claim 13, wherein said selection step comprises performing control such that some speech segments are not decoded.

19. A speech information processing apparatus for synthesizing speech by using a speech segment dictionary for holding a plurality of speech segments, comprising:

selecting means for selecting, from a plurality of decoding methods, a decoding method of decoding a speech segment read out from the speech segment dictionary;

decoding means for decoding the speech segment by using the selected decoding method; and

speech synthesizing means for synthesizing speech on the basis of the decoded speech segment.

20. The apparatus according to claim 19, wherein one of the plurality of decoding methods differs from other decoding methods in the number of quantization steps.

21. The apparatus according to claim 19, wherein one of the plurality of decoding methods differs from other decoding methods in a quantization code book.

22. The apparatus according to claim 19, wherein one of the plurality of decoding methods differs from other decoding methods in a decoding scheme.

23. The apparatus according to claim 19, wherein one of the plurality of decoding methods uses one of a μ-law scheme, scalar quantization, and linear predictive coding.

24. The apparatus according to claim 19, wherein said selecting means performs control such that some speech segments are not decoded.

25. A speech information processing method of generating a speech segment dictionary for holding a plurality of speech segments, comprising:

a setting step of setting an encoding method of encoding a speech segment in accordance with the type of the speech segment;

a encoding step of encoding the speech segment by using the set encoding method; and

a storage step of storing the encoded speech segment in a speech segment dictionary.

26. The method according to claim 25, wherein said setting step comprises changing an encoding method to be set for the speech segment in accordance with whether the type of the speech segment is a plosive or not.

27. The method according to claim 25, wherein said setting step comprises performing setting such that the speech segment is not encoded if the type of the speech segment is a plosive.

28. The method according to claim 25, wherein said setting step comprises changing an encoding method to be set for the speech segment in accordance with whether the type of the speech segment is an unvoiced sound or not.

29. The method according to claim 25, wherein said setting step comprises changing an encoding method to be set for the speech segment in accordance with whether the type of the speech segment is a nasal sound or not.

30. A speech information processing apparatus for generating a speech segment dictionary for holding a plurality of speech segments, comprising:

setting means for setting an encoding method of encoding a speech segment in accordance with the type of the speech segment;

encoding means for encoding the speech segment by using the set encoding method; and

storage means for storing the encoded speech segment in a speech segment dictionary.

31. The apparatus according to claim 30, wherein said setting means changes an encoding method to be set for the speech segment in accordance with whether the type of the speech segment is a plosive or not.

32. The apparatus according to claim 30, wherein said setting means performs setting such that the speech segment is not encoded if the type of the speech segment is a plosive.

33. The apparatus according to claim 30, wherein said setting means changes an encoding method to be set for the speech segment in accordance with whether the type of the speech segment is an unvoiced sound or not.

34. The apparatus according to claim 30, wherein said setting means changes an encoding method to be set for the speech segment in accordance with whether the type of the speech segment is a nasal sound or not.

35. A speech information processing method of synthesizing speech by using a speech segment dictionary for holding a plurality of speech segments, comprising:

a setting step of setting a decoding method of decoding a speech segment read out from the speech segment dictionary in accordance with the type of the speech segment;

a decoding step of decoding the speech segment by using the set decoding method; and

a speech synthesizing step of synthesizing speech on the basis of the decoded speech segment.

36. The method according to claim 35, wherein said setting step comprises changing a decoding method to be set for the speech segment in accordance with whether the type of the speech segment is a plosive or not.

37. The method according to claim 35, wherein said setting step comprises performing setting such that the speech segment is not decoded if the type of the speech segment is a plosive.

38. The method according to claim 35, wherein said setting step comprises changing a decoding method to be set for the speech segment in accordance with whether the type of the speech segment is an unvoiced sound or not.

39. The method according to claim 35, wherein said setting step comprises changing a decoding method to be set for the speech segment in accordance with whether the type of the speech segment is a nasal sound or not.

40. A speech information processing apparatus for synthesizing speech by using a speech segment dictionary for holding a plurality of speech segments, comprising:

setting means for setting a decoding method of decoding a speech segment read out from the speech segment dictionary in accordance with the type of the speech segment;

decoding means for decoding the speech segment by using the set decoding method; and

speech synthesizing means for synthesizing speech on the basis of the decoded speech segment.

41. The apparatus according to claim 40, wherein said setting means changes a decoding method to be set for the speech segment in accordance with whether the type of the speech segment is a plosive or not.

42. The apparatus according to claim 40, wherein said setting means performs setting such that the speech segment is not decoded if the type of the speech segment is a plosive.

43. The apparatus according to claim 40, wherein said setting means changes a decoding method to be set for the speech segment in accordance with whether the type of the speech segment is an unvoiced sound or not.

44. The apparatus according to claim 40, wherein said setting means changes a decoding method to be set for the speech segment in accordance with whether the type of the speech segment is a nasal sound or not.

45. A storage medium storing a control program for allowing a computer to realize the speech information processing method according to claim 1.

46. A storage medium storing a control program for allowing a computer to realize the speech information processing method according to claim 13.

47. A storage medium storing a control program for allowing a computer to realize the speech information processing method according to claim 25.

48. A storage medium storing a control program for allowing a computer to realize the speech information processing method according to claim 35.

ABSTRACT OF THE DISCLOSURE

N speech segment data are encoded in accordance with their respective optimum encoding schemes. The speech segment data thus encoded are registered in a speech segment dictionary along with information specifying the encoding methods used in the encoding.

FIG. 1

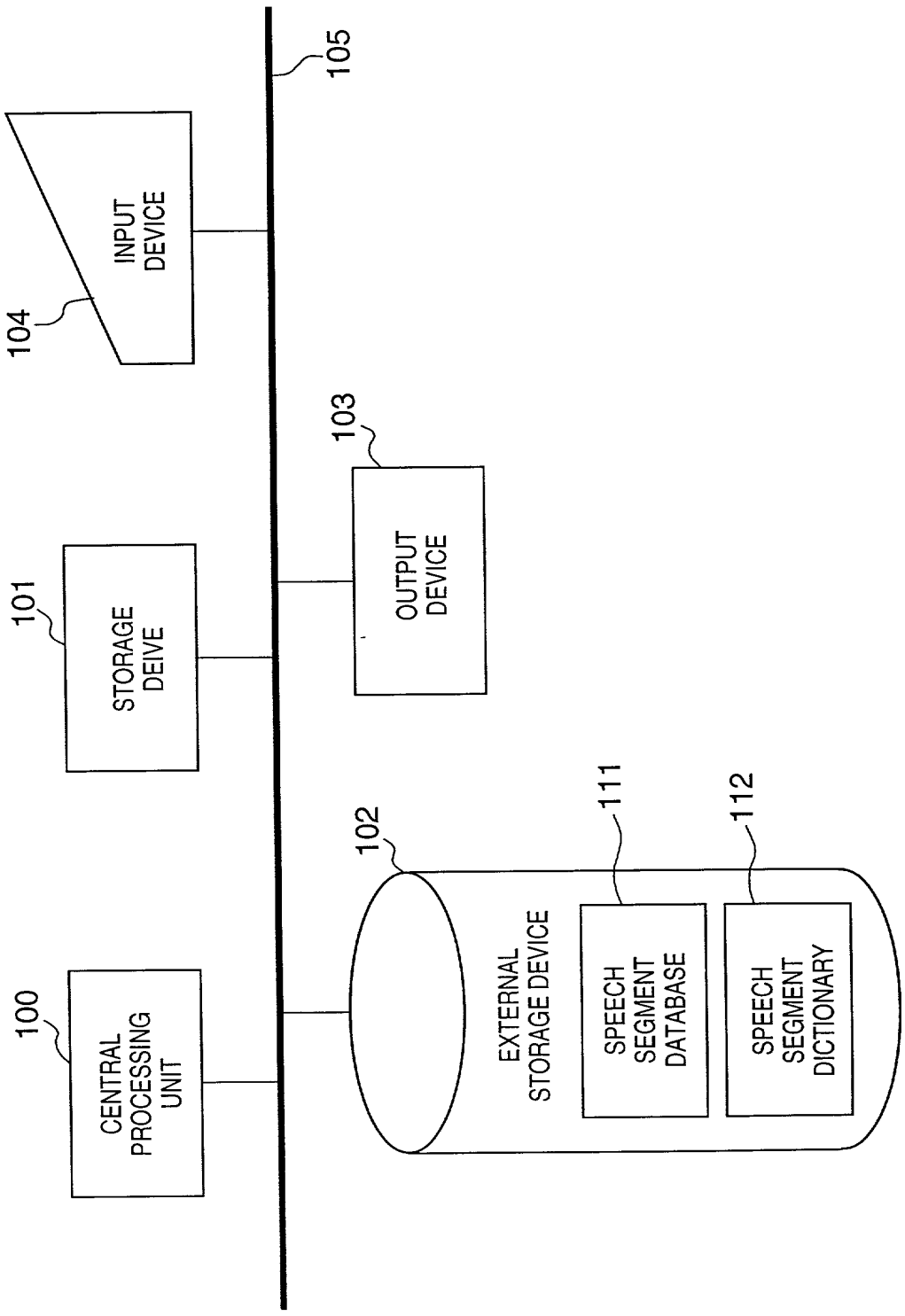

105
INPUT DEVICE
104
OUTPUT DEVICE
103
STORAGE DEIVE
101
CENTRAL PROCESSING UNIT
100
102
EXTERNAL STORAGE DEVICE
SPEECH SEGMENT DATABASE
111
SPEECH SEGMENT DICTIONARY
112

FIG. 2

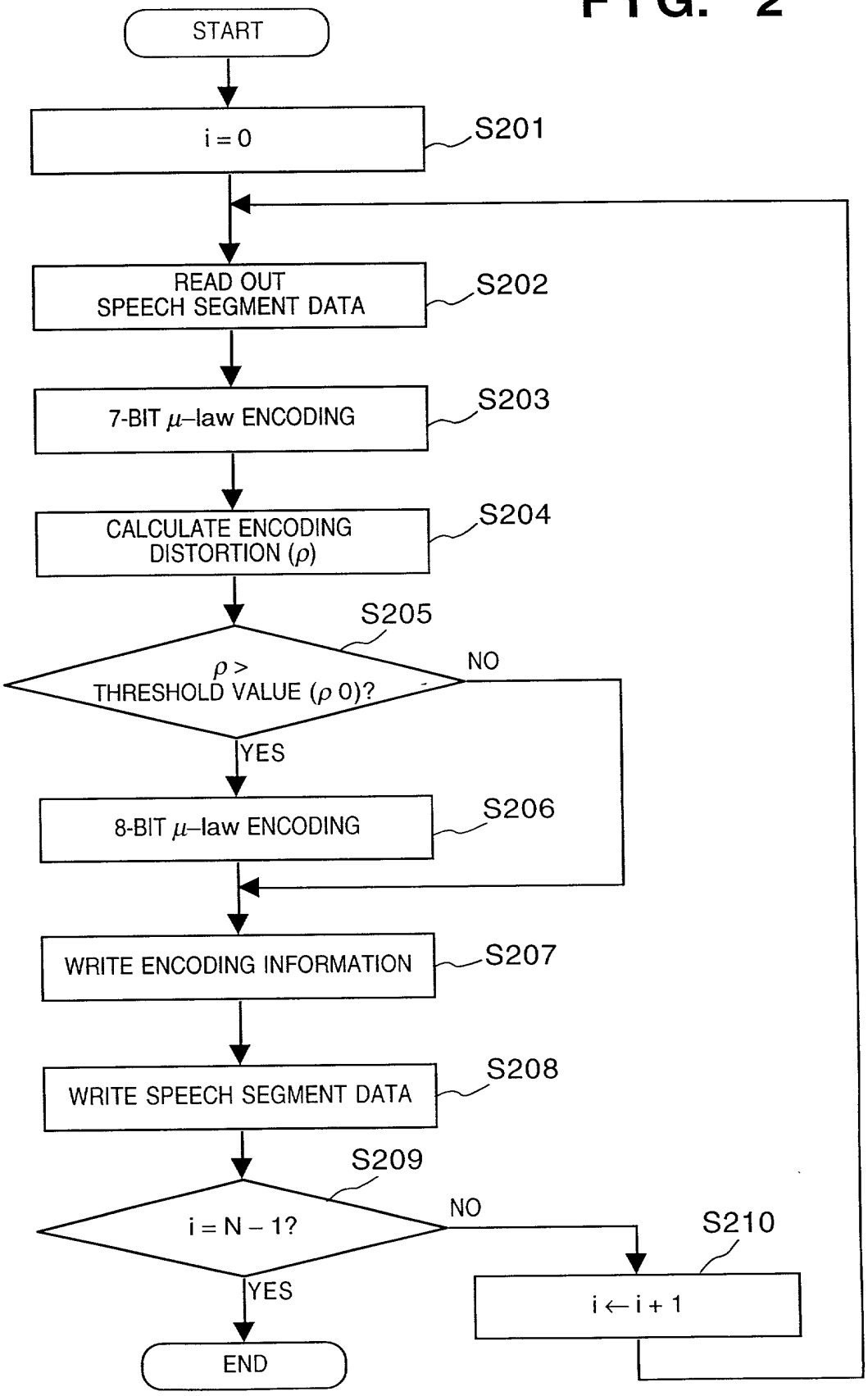

START
i = 0
S201
READ OUT SPEECH SEGMENT DATA
S202
7-BIT μ–law ENCODING
S203
CALCULATE ENCODING DISTORTION (ρ)
S204
S205
ρ > THRESHOLD VALUE (ρ 0)?
NO
YES
8-BIT μ–law ENCODING
S206
WRITE ENCODING INFORMATION
S207
WRITE SPEECH SEGMENT DATA
S208
S209
i = N – 1?
NO
YES
S210
i ← i + 1
END

FIG. 3

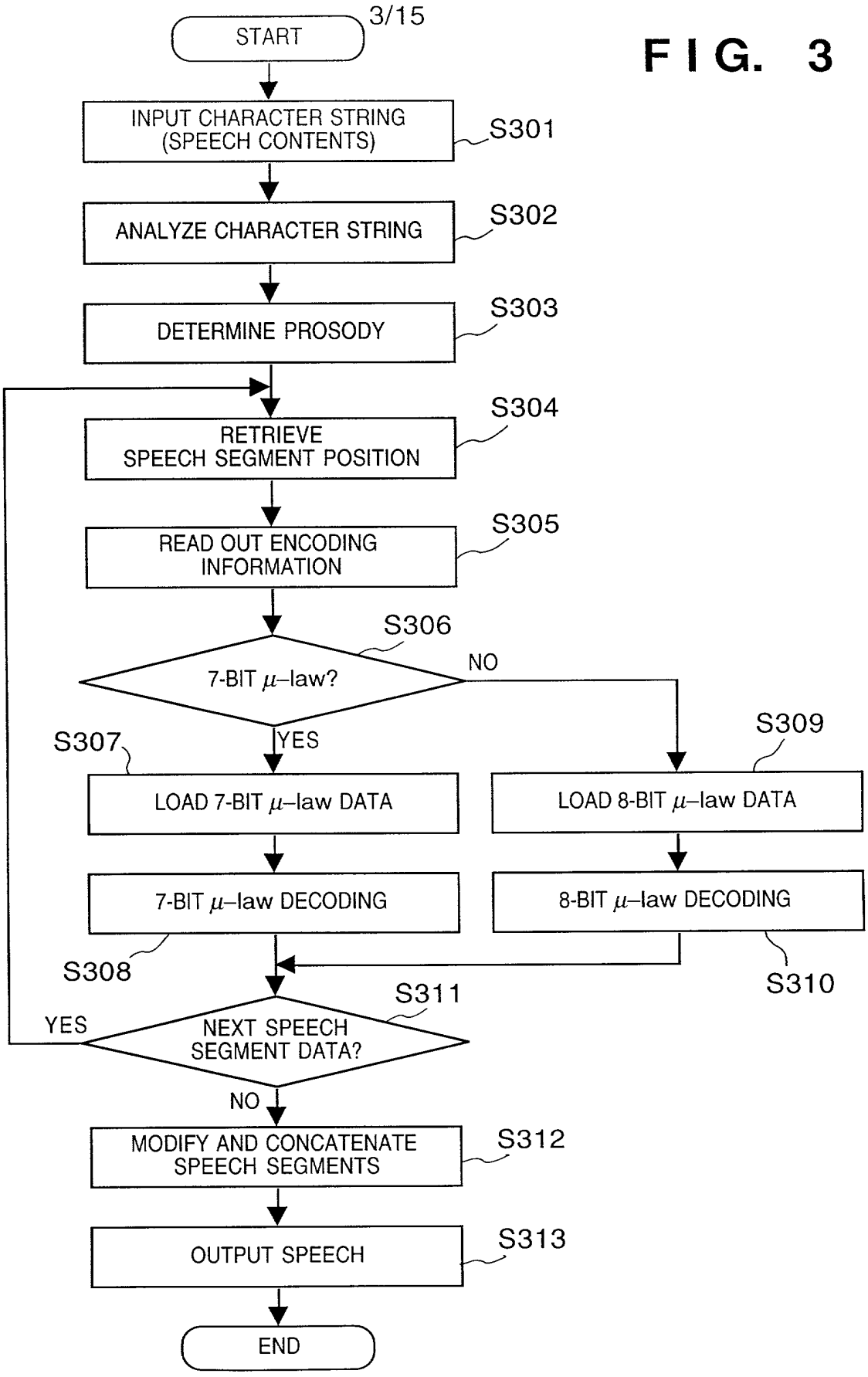

START
INPUT CHARACTER STRING (SPEECH CONTENTS)
S301
ANALYZE CHARACTER STRING
S302
DETERMINE PROSODY
S303
RETRIEVE SPEECH SEGMENT POSITION
S304
READ OUT ENCODING INFORMATION
S305
7-BIT μ–law?
S306
NO
YES
LOAD 7-BIT μ–law DATA
S307
LOAD 8-BIT μ–law DATA
S309
7-BIT μ–law DECODING
8-BIT μ–law DECODING
S308
S310
NEXT SPEECH SEGMENT DATA?
S311
YES
NO
MODIFY AND CONCATENATE SPEECH SEGMENTS
S312
OUTPUT SPEECH
S313
END

FIG. 4

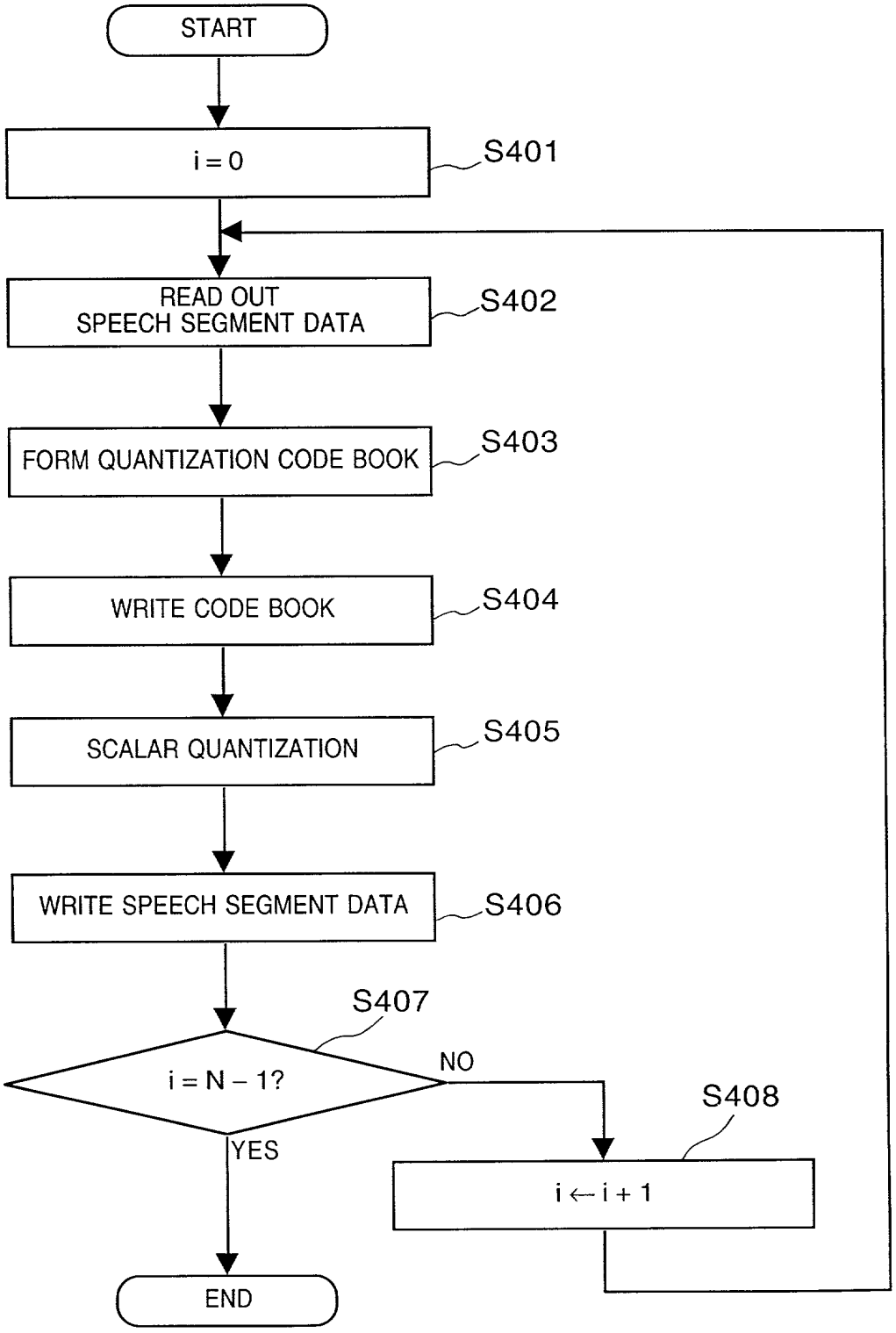

START
i = 0
S401
READ OUT SPEECH SEGMENT DATA
S402
FORM QUANTIZATION CODE BOOK
S403
WRITE CODE BOOK
S404
SCALAR QUANTIZATION
S405
WRITE SPEECH SEGMENT DATA
S406
S407
i = N – 1?
NO
YES
S408
i ← i + 1
END

FIG. 5

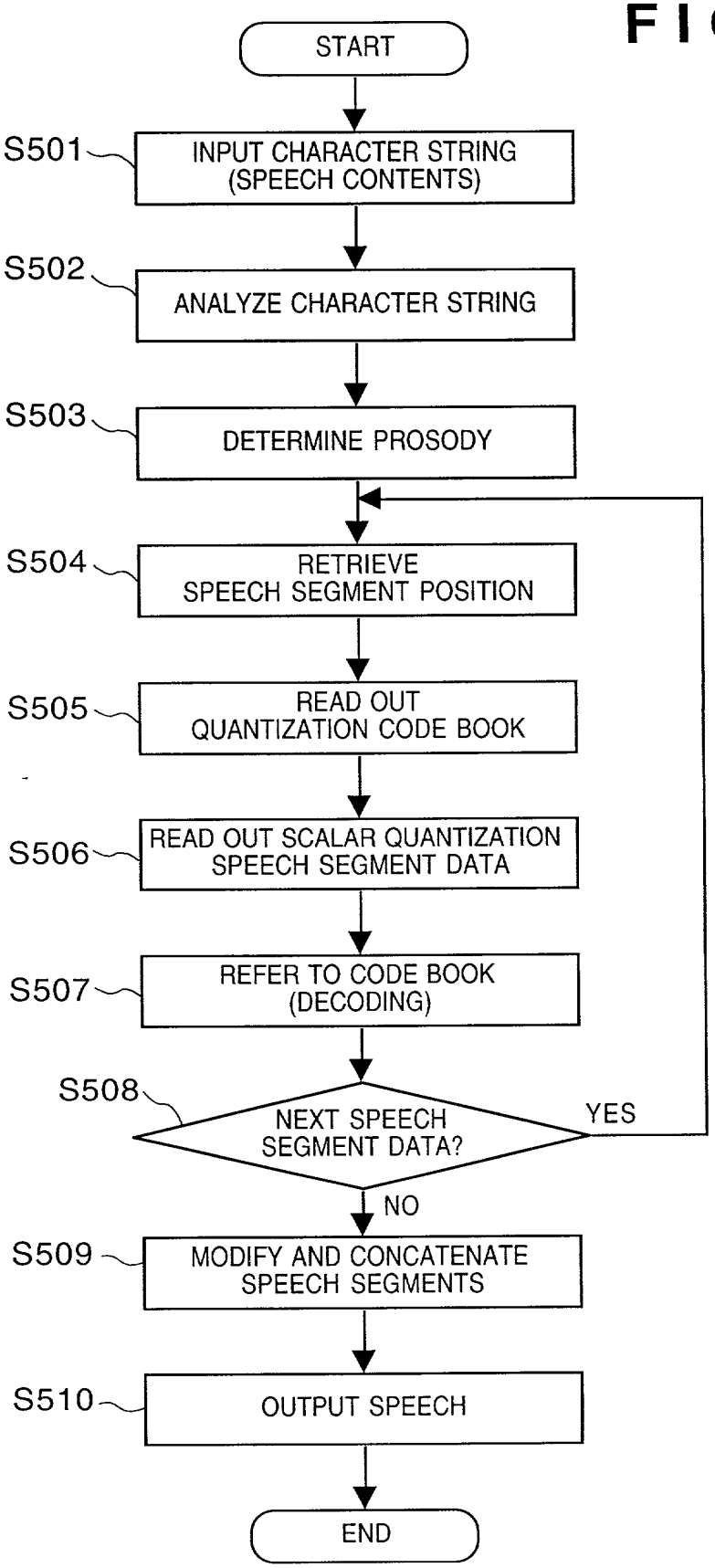

START
S501
INPUT CHARACTER STRING (SPEECH CONTENTS)
S502
ANALYZE CHARACTER STRING
S503
DETERMINE PROSODY
S504
RETRIEVE SPEECH SEGMENT POSITION
S505
READ OUT QUANTIZATION CODE BOOK
S506
READ OUT SCALAR QUANTIZATION SPEECH SEGMENT DATA
S507
REFER TO CODE BOOK (DECODING)
S508
NEXT SPEECH SEGMENT DATA?
YES
NO
S509
MODIFY AND CONCATENATE SPEECH SEGMENTS
S510
OUTPUT SPEECH
END

FIG. 6

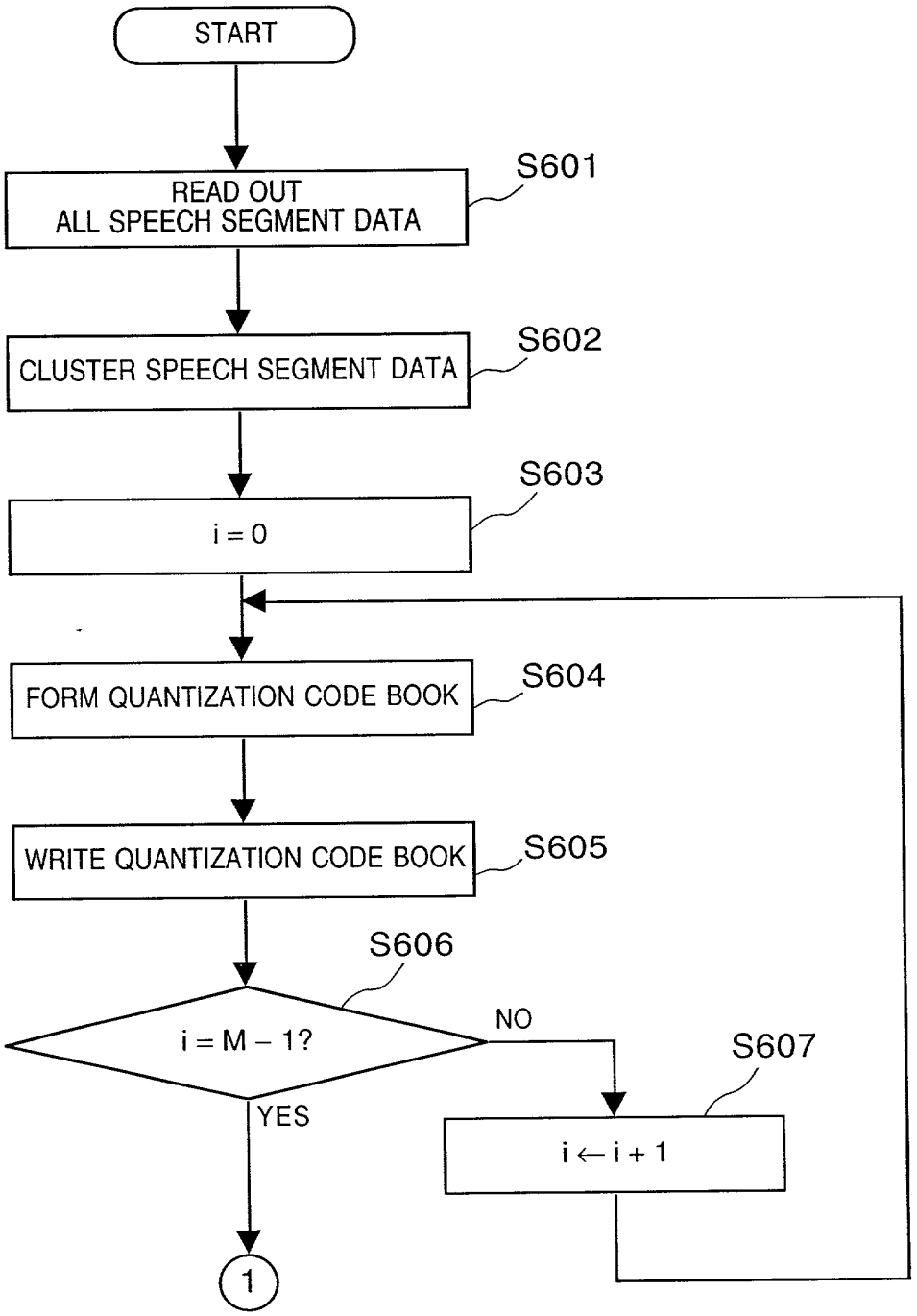

START
READ OUT
ALL SPEECH SEGMENT DATA
S601
CLUSTER SPEECH SEGMENT DATA
S602
i = 0
S603
FORM QUANTIZATION CODE BOOK
S604
WRITE QUANTIZATION CODE BOOK
S605
S606
i = M – 1?
NO
YES
S607
i ← i + 1
1

FIG. 7

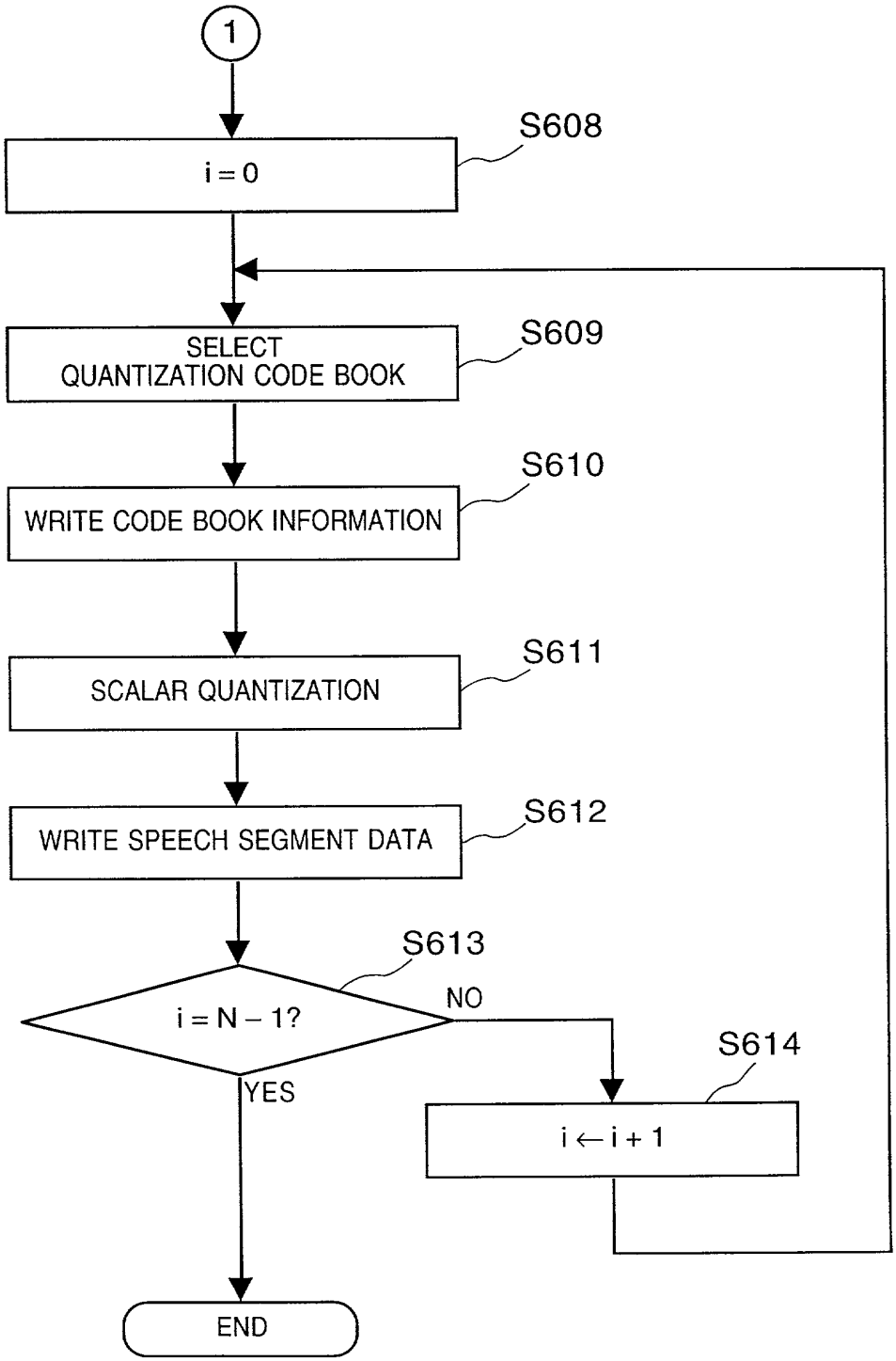

1
S608
i = 0
S609
SELECT QUANTIZATION CODE BOOK
S610
WRITE CODE BOOK INFORMATION
S611
SCALAR QUANTIZATION
S612
WRITE SPEECH SEGMENT DATA
S613
i = N – 1?
NO
YES
S614
i ← i + 1
END

FIG. 8

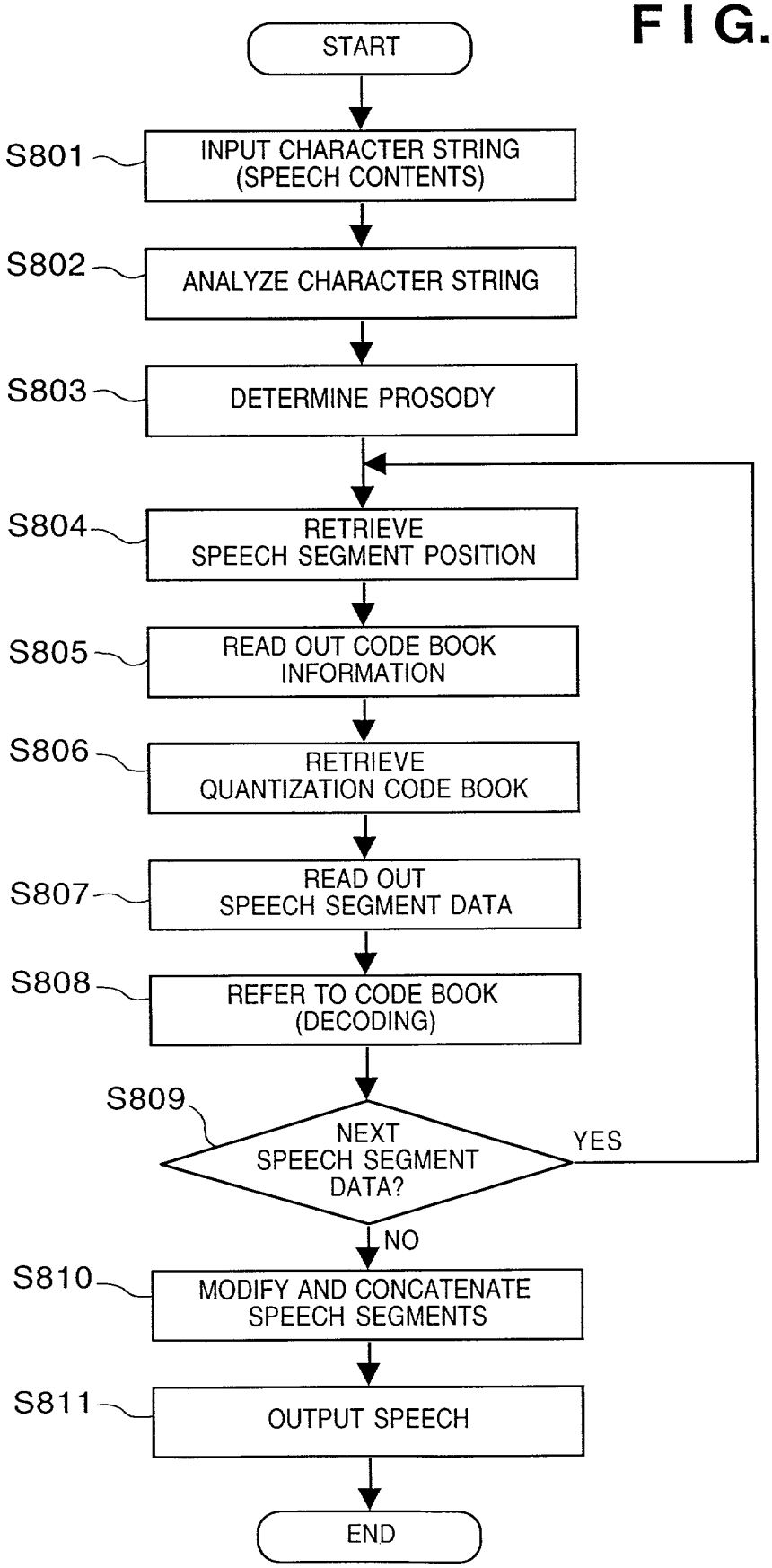

START
S801
INPUT CHARACTER STRING (SPEECH CONTENTS)
S802
ANALYZE CHARACTER STRING
S803
DETERMINE PROSODY
S804
RETRIEVE SPEECH SEGMENT POSITION
S805
READ OUT CODE BOOK INFORMATION
S806
RETRIEVE QUANTIZATION CODE BOOK
S807
READ OUT SPEECH SEGMENT DATA
S808
REFER TO CODE BOOK (DECODING)
S809
NEXT SPEECH SEGMENT DATA?
YES
NO
S810
MODIFY AND CONCATENATE SPEECH SEGMENTS
S811
OUTPUT SPEECH
END

FIG. 9

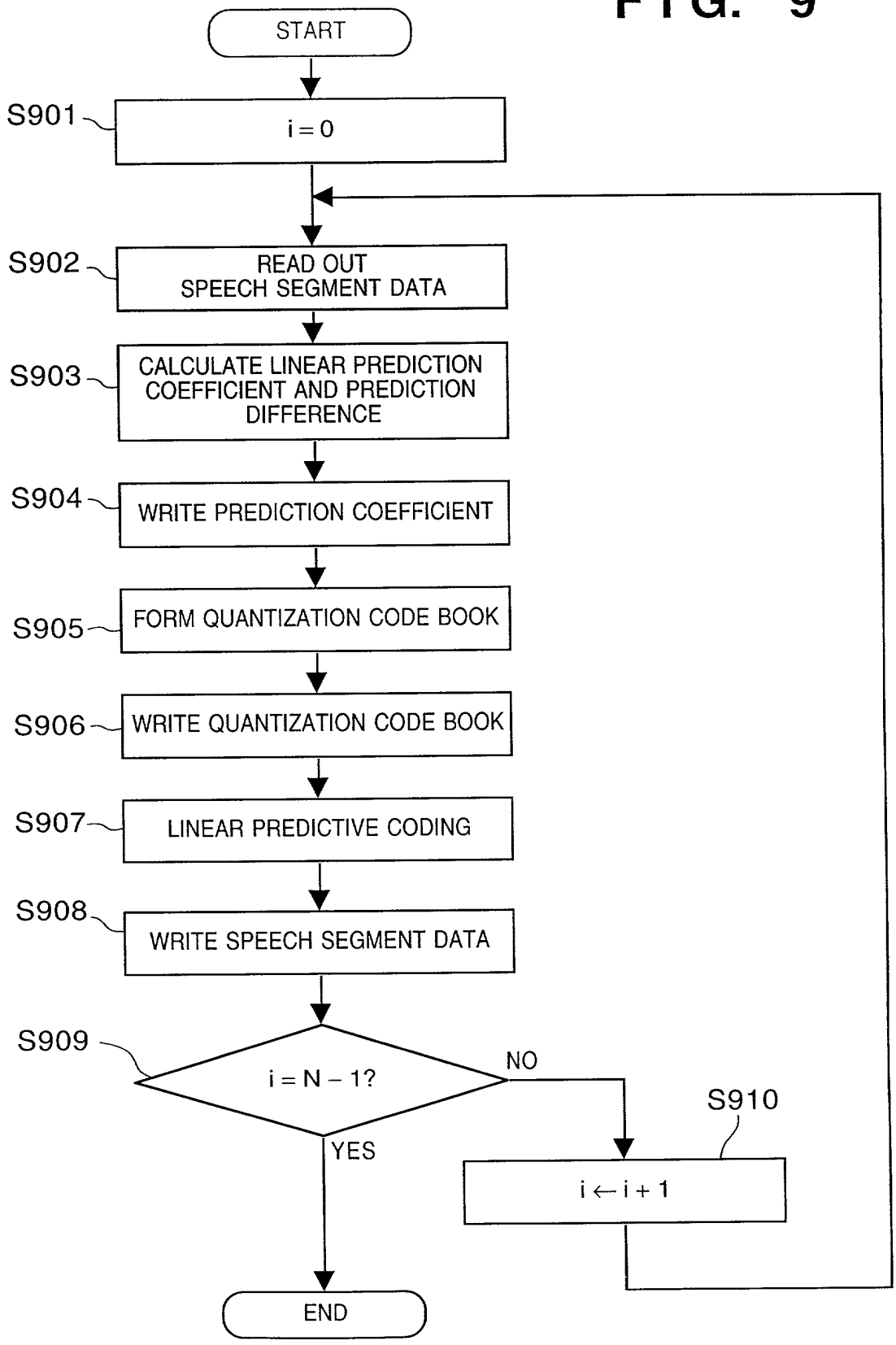

START
S901
i = 0
S902
READ OUT SPEECH SEGMENT DATA
S903
CALCULATE LINEAR PREDICTION COEFFICIENT AND PREDICTION DIFFERENCE
S904
WRITE PREDICTION COEFFICIENT
S905
FORM QUANTIZATION CODE BOOK
S906
WRITE QUANTIZATION CODE BOOK
S907
LINEAR PREDICTIVE CODING
S908
WRITE SPEECH SEGMENT DATA
S909
i = N – 1?
NO
YES
S910
i ← i + 1
END

FIG. 10

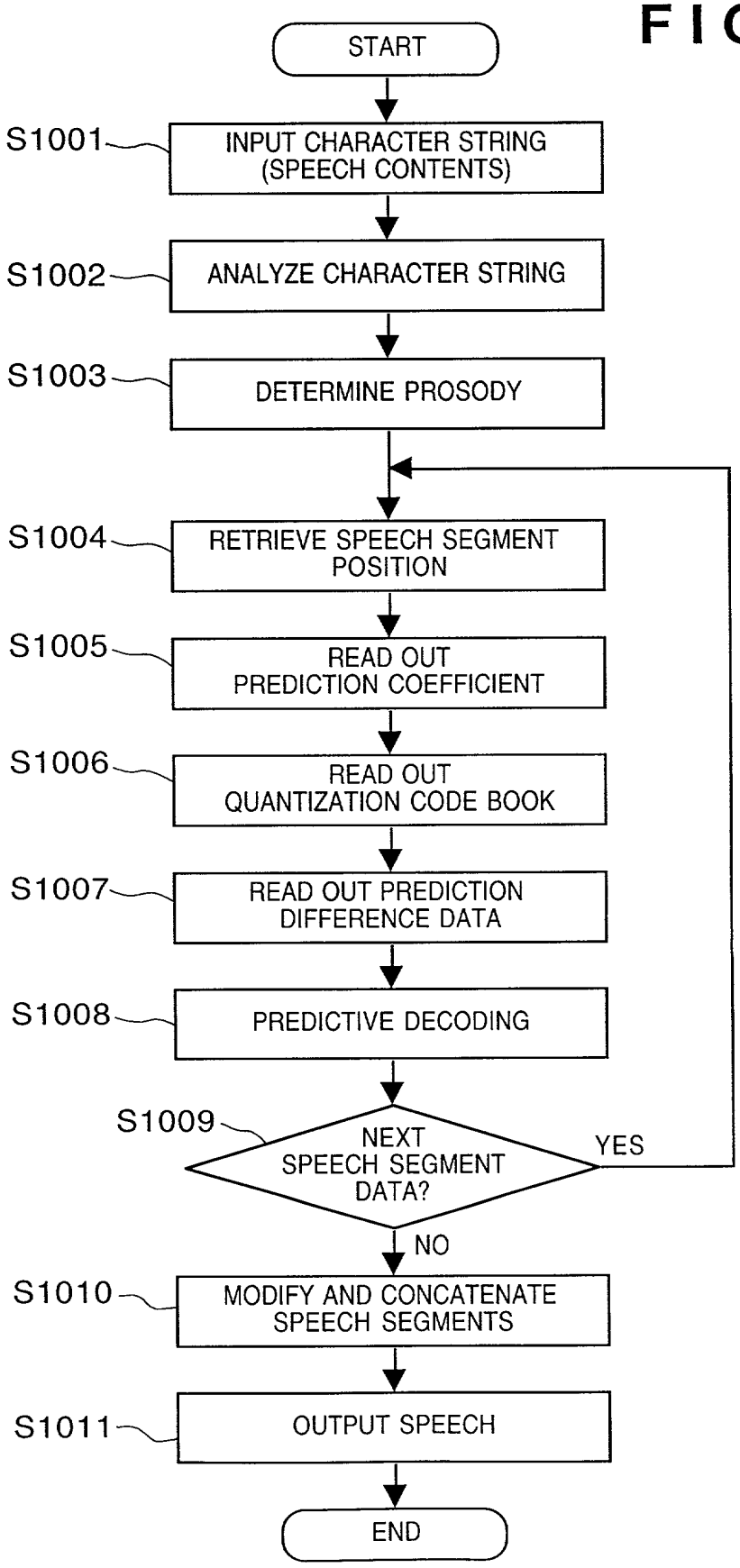

START
S1001
INPUT CHARACTER STRING (SPEECH CONTENTS)
S1002
ANALYZE CHARACTER STRING
S1003
DETERMINE PROSODY
S1004
RETRIEVE SPEECH SEGMENT POSITION
S1005
READ OUT PREDICTION COEFFICIENT
S1006
READ OUT QUANTIZATION CODE BOOK
S1007
READ OUT PREDICTION DIFFERENCE DATA
S1008
PREDICTIVE DECODING
S1009
NEXT SPEECH SEGMENT DATA?
YES
NO
S1010
MODIFY AND CONCATENATE SPEECH SEGMENTS
S1011
OUTPUT SPEECH
END

FIG. 11

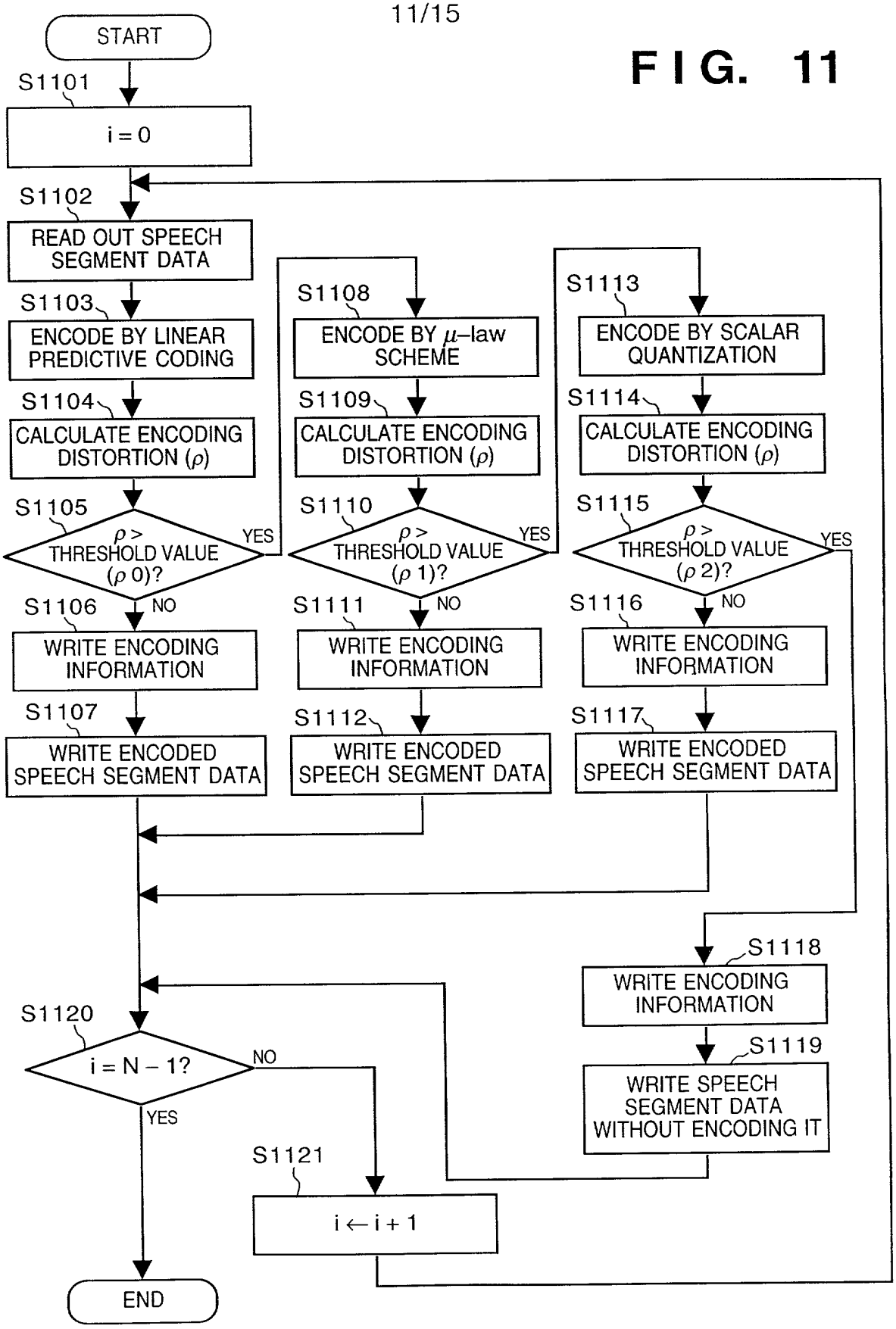

START
S1101
i = 0
S1102
READ OUT SPEECH SEGMENT DATA
S1103
ENCODE BY LINEAR PREDICTIVE CODING
S1104
CALCULATE ENCODING DISTORTION (ρ)
S1105
ρ > THRESHOLD VALUE (ρ 0)?
YES
NO
S1106
WRITE ENCODING INFORMATION
S1107
WRITE ENCODED SPEECH SEGMENT DATA
S1108
ENCODE BY μ-law SCHEME
S1109
CALCULATE ENCODING DISTORTION (ρ)
S1110
ρ > THRESHOLD VALUE (ρ 1)?
YES
NO
S1111
WRITE ENCODING INFORMATION
S1112
WRITE ENCODED SPEECH SEGMENT DATA
S1113
ENCODE BY SCALAR QUANTIZATION
S1114
CALCULATE ENCODING DISTORTION (ρ)
S1115
ρ > THRESHOLD VALUE (ρ 2)?
YES
NO
S1116
WRITE ENCODING INFORMATION
S1117
WRITE ENCODED SPEECH SEGMENT DATA
S1118
WRITE ENCODING INFORMATION
S1119
WRITE SPEECH SEGMENT DATA WITHOUT ENCODING IT
S1120
i = N – 1?
NO
YES
S1121
i ← i + 1
END

FIG. 12

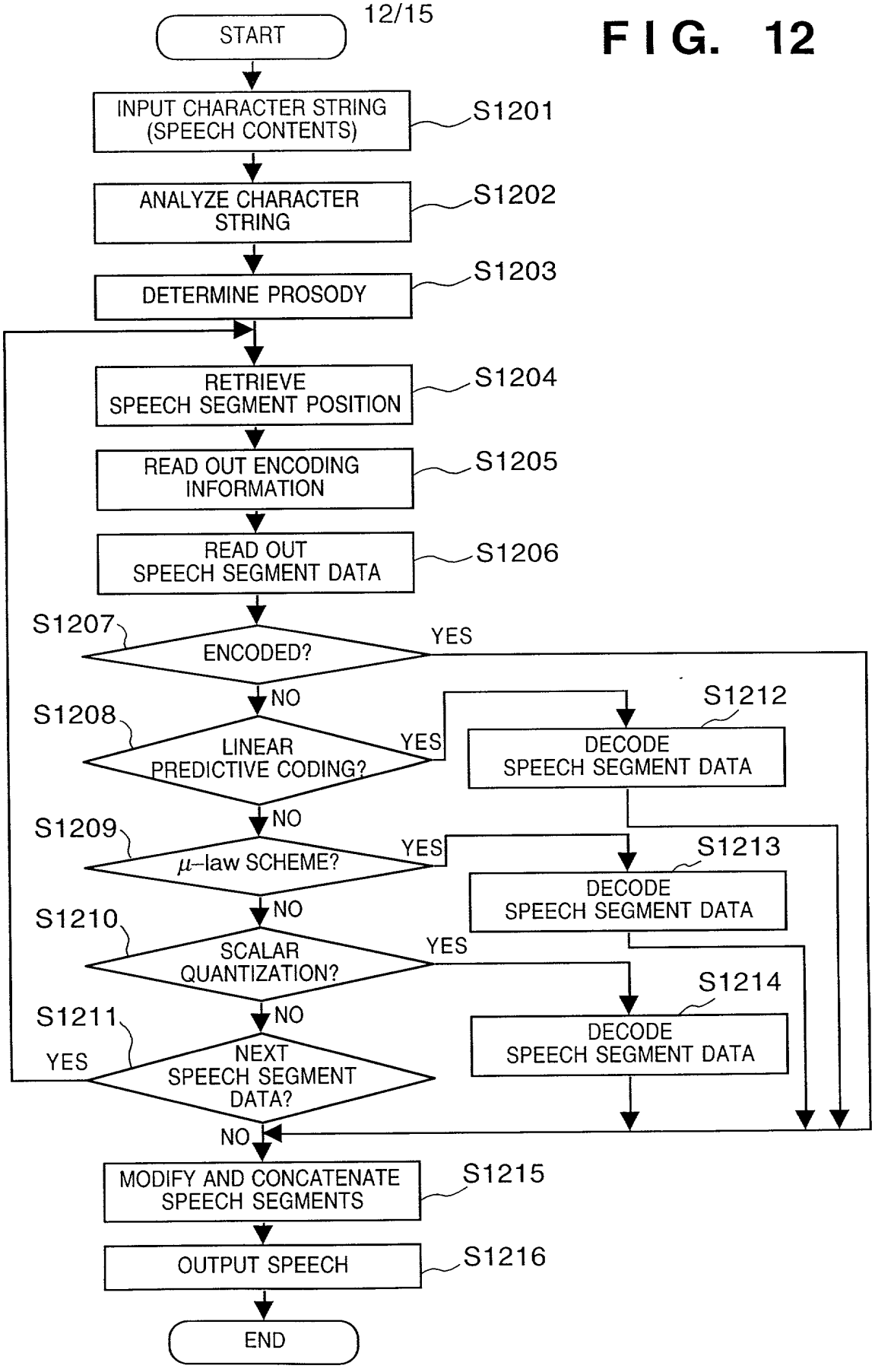


FIG. 13

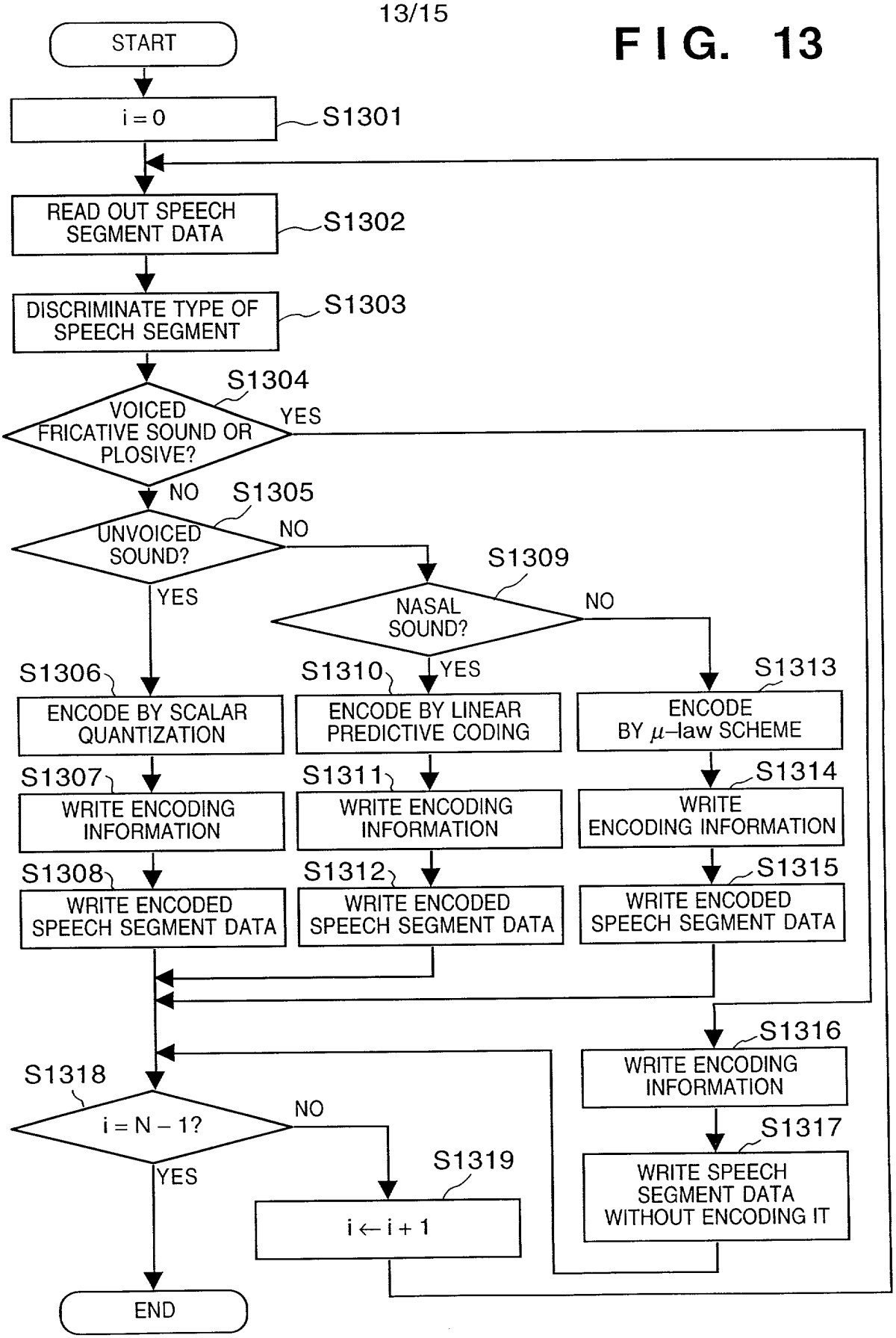

START
i = 0
S1301
READ OUT SPEECH SEGMENT DATA
S1302
DISCRIMINATE TYPE OF SPEECH SEGMENT
S1303
S1304
VOICED FRICATIVE SOUND OR PLOSIVE?
YES
NO
S1305
UNVOICED SOUND?
NO
YES
S1309
NASAL SOUND?
NO
YES
S1306
ENCODE BY SCALAR QUANTIZATION
S1310
ENCODE BY LINEAR PREDICTIVE CODING
S1313
ENCODE BY μ-law SCHEME
S1307
WRITE ENCODING INFORMATION
S1311
WRITE ENCODING INFORMATION
S1314
WRITE ENCODING INFORMATION
S1308
WRITE ENCODED SPEECH SEGMENT DATA
S1312
WRITE ENCODED SPEECH SEGMENT DATA
S1315
WRITE ENCODED SPEECH SEGMENT DATA
S1316
WRITE ENCODING INFORMATION
S1317
WRITE SPEECH SEGMENT DATA WITHOUT ENCODING IT
S1318
i = N – 1?
NO
YES
S1319
i ← i + 1
END

FIG. 14

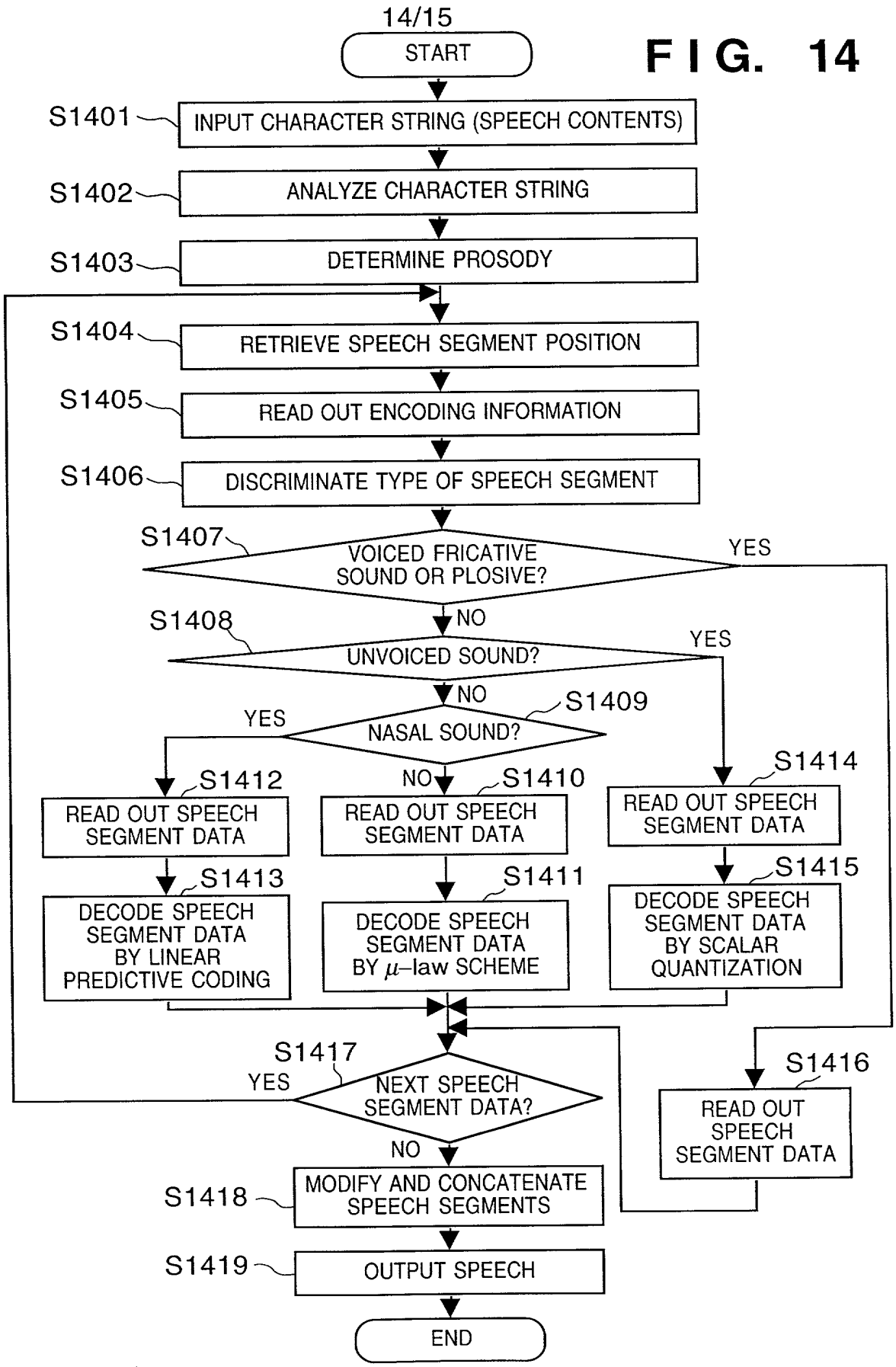
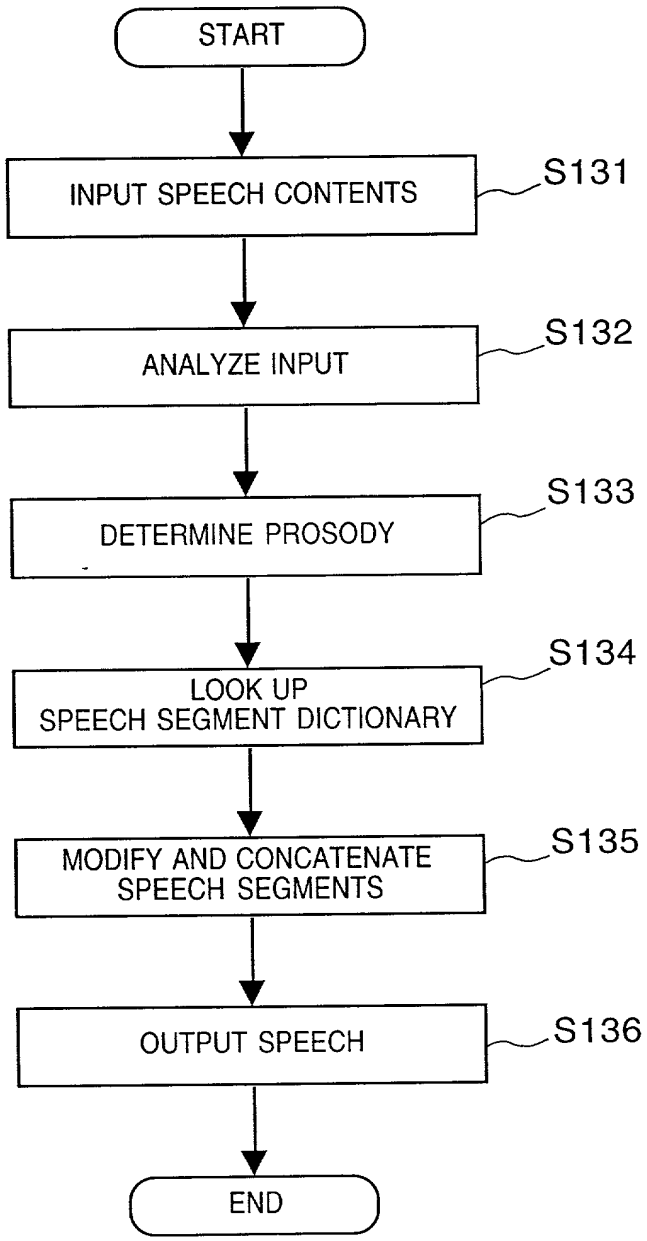

START
S1401
INPUT CHARACTER STRING (SPEECH CONTENTS)
S1402
ANALYZE CHARACTER STRING
S1403
DETERMINE PROSODY
S1404
RETRIEVE SPEECH SEGMENT POSITION
S1405
READ OUT ENCODING INFORMATION
S1406
DISCRIMINATE TYPE OF SPEECH SEGMENT
S1407
VOICED FRICATIVE SOUND OR PLOSIVE?
YES
NO
S1408
UNVOICED SOUND?
YES
NO
S1409
NASAL SOUND?
YES
NO
S1412
READ OUT SPEECH SEGMENT DATA
S1413
DECODE SPEECH SEGMENT DATA BY LINEAR PREDICTIVE CODING
S1410
READ OUT SPEECH SEGMENT DATA
S1411
DECODE SPEECH SEGMENT DATA BY μ–law SCHEME
S1414
READ OUT SPEECH SEGMENT DATA
S1415
DECODE SPEECH SEGMENT DATA BY SCALAR QUANTIZATION
S1417
NEXT SPEECH SEGMENT DATA?
YES
NO
S1416
READ OUT SPEECH SEGMENT DATA
S1418
MODIFY AND CONCATENATE SPEECH SEGMENTS
S1419
OUTPUT SPEECH
END

FIG. 15


START
INPUT SPEECH CONTENTS
S131
ANALYZE INPUT
S132
DETERMINE PROSODY
S133
LOOK UP
SPEECH SEGMENT DICTIONARY
S134
MODIFY AND CONCATENATE
SPEECH SEGMENTS
S135
OUTPUT SPEECH
S136
END